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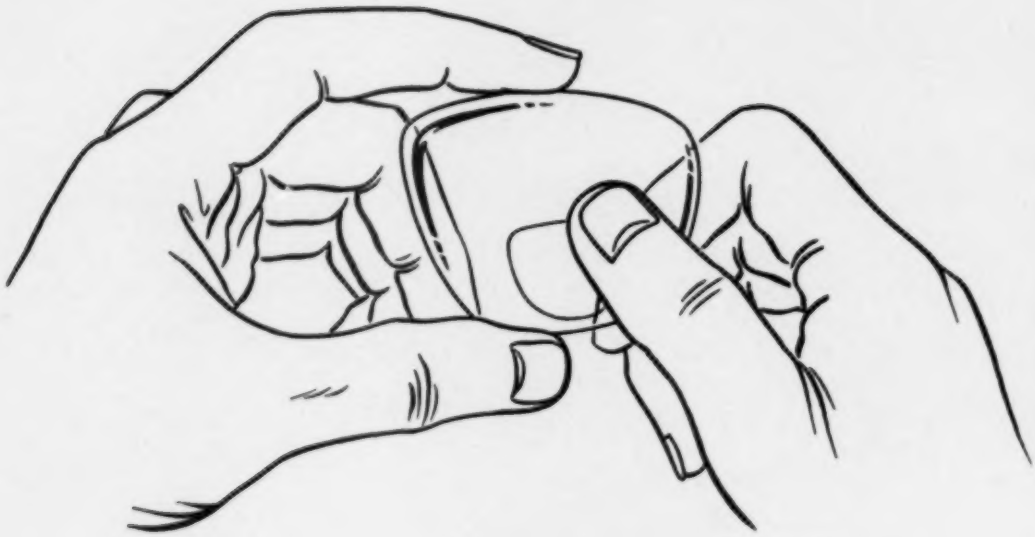

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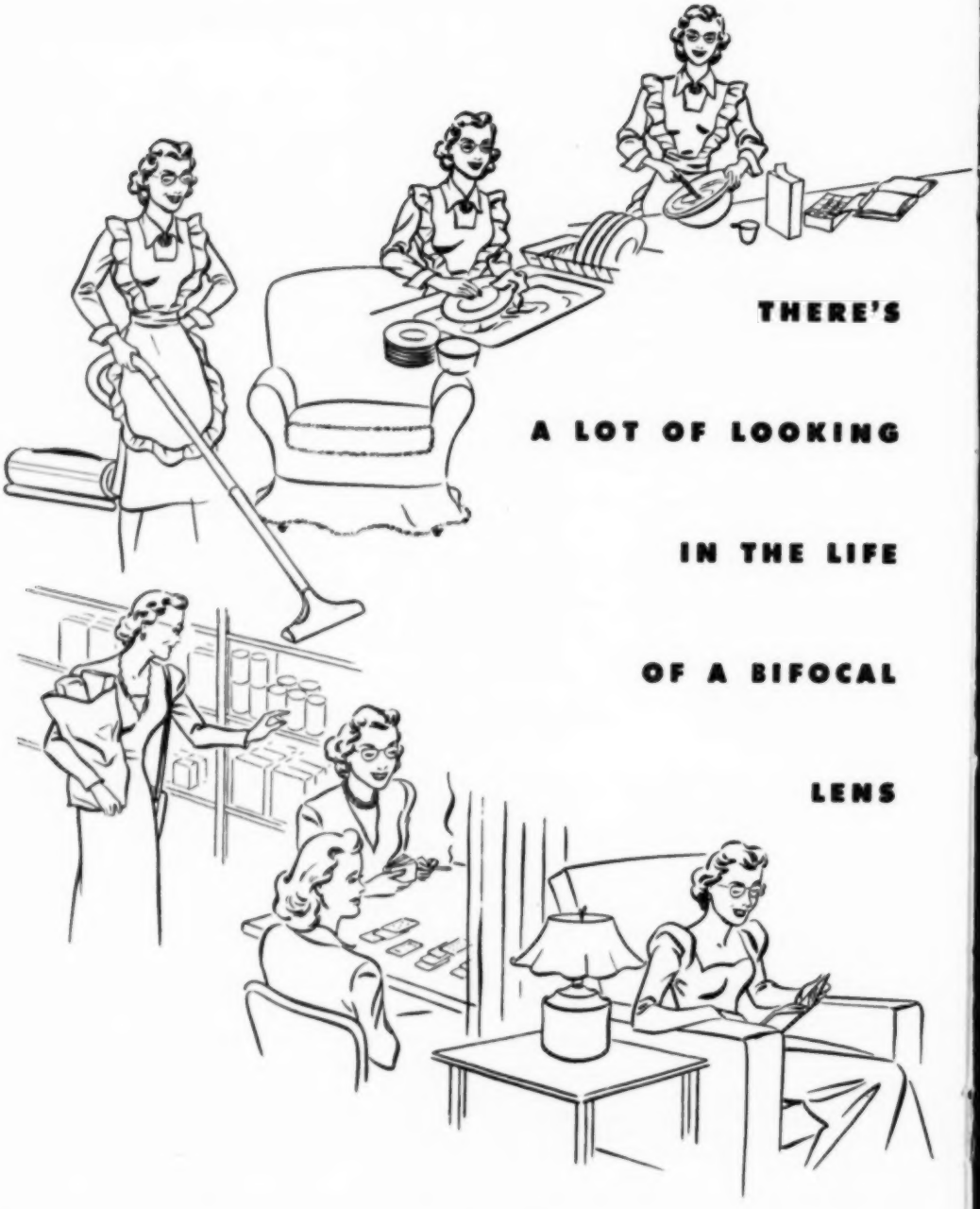

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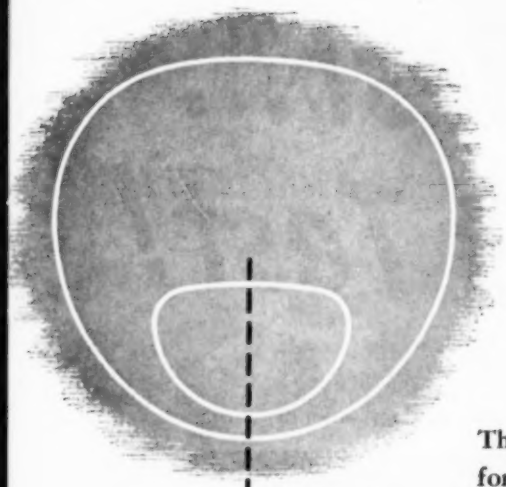
A LOT OF LOOKING

IN THE LIFE

OF A BIFOCAL

LENS



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THE SPECIFICATION OF COLOR OF OPHTHALMIC GLASSES*

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Bausch & Lomb Optical Company
Rochester, New York

It is the purpose of this paper to explain the scientific basis of color: to describe briefly the principal system of color notation: to explain how these systems are used in the establishment of manufacturing specifications for various colored glasses, and to discuss a few applications of color selection in ophthalmic lenses in which both the professional man and the glassmaker are interested.

What is color? To define the word in terms acceptable to everyone is not an easy task, since it is commonly used in several different senses. Webster gives as the first and general definition "a quality of visible phenomena, distinct from form and from light and shade." The dictionary goes on to define color in the psycho-physical sense, as "a sensation evoked as a specific response to stimulation of the eye and its attached nervous mechanisms by radiant energy of certain wavelengths and intensities."

The Optical Society of America has defined color as "the characteristics of light other than spatial and temporal inhomogenities, light being that aspect of radiant energy of which a human observer is aware through the visual sensations which arise from the stimulation of the retina of the eye."

Today we have a science of color: it can be measured and expressed in numbers, just as temperature is measured and expressed in numbers. A specification of color is the establishment of a proper order of these numbers.

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*Read before the annual meeting of the American Academy of Optometry, Rochester, New York, December 8, 1952. For publication in the July, 1953, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Ph.D.

The sensation of color may be expressed in three parameters. The first of these is brightness and refers to the quantity of energy reaching the eye. It is variously referred to as brightness, lightness, visible transmittance or reflectance, value, or subjective intensity.

The other two parameters express chromaticity, which is independent of the light-dark variable. The first is that by which an object is observed to be red, or green, or blue. It is called hue, dominant hue, tint, or simply color. The other is that by which is distinguished the amount of concentration of hue, or, in other words, the degree of departure of a hue from white or gray. It is referred to as saturation, purity, chroma, concentration, or intensity of hue.

The various terms used in the description of each of these components are closely related to one another but are not synonymous. Purity and saturation are not synonymous; neither are brightness and lightness. The exact meaning of each term depends upon the sense in which it is used—whether it is physical or psychological, objective or subjective.

The technical, scientific definitions do not help a great deal in an effort to get a true understanding of the problem of specifying color. On the one hand, the purely physical aspects of color may be reduced to a system of numbers by the physicist or colorimetrist. He considers black to be a color, because it can be expressed by two or three zeros. On the other hand, the phychological aspects—the stimulus evoked by the radiant energy, the reception of the stimulus by the eye, and the resulting visual sensation which we experience—are a different matter. They cannot be reduced to any system of numbers; here the physical sciences are of no help. Mentioned previously was the fact that color can be expressed in numbers and that a specification of color is the establishment of a proper order of these numbers, but the problem goes a great deal further than this. In order to develop a color notation system which will be at all useful—and we must have this before we can consider setting up color specifications for absorbtive glasses or for anything else—we must establish some sort of reasonable, logical relation between the physical measurement of color and its psychological perception. Neither of these, by itself, is sufficient to allow us to establish a usable color notation. The physical measurement does not in any way indicate to us how we see the color, and without the physical measurement the psychologist has no basis on which to build a system. We therefore must proceed upon the premise that the numerical data obtained from the physical measurement must be translated into a system which embraces the subjective, visual aspects of color.

A reasonable point at which to start is the use of the fact that color may be broken down into three distinct components or parameters, each of which is variable, but which taken together form a sound basis for establishing a color notation. One of the most plausible efforts directed toward accomplishing this task was brought forth some years ago by Albert H. Munsell, artist and teacher, who dedicated most of his lifetime to the task of establishing an orderly color notation. Munsell proposed to set up a series of colored papers which varied equally in all directions in the color space in terms of visual appearance. He succeeded in producing a color atlas containing samples of colors which varied in roughly uniform steps over a large part of the range of surface colors.

Munsell defined the three variables of color as value, hue, and chroma. These he constructed into a three-dimensional color solid, the vertical axis being the black-to-white, or value, scale. Around this he arranged the hues in equal angular spacing and defined chroma as the distance outward from the axis at any particular value level. Figure 1 shows Munsell's arrangement of the three color parameters, which forms the basis of his color solid. Figure 2 is a representation of the color solid, each segment being one of the ten basic hues. It is observed that at the extremes of the value scale—the vertical dimension of the solid—there are no colors of high saturation, or chroma; actually, high chromas at the very low and very high value levels do

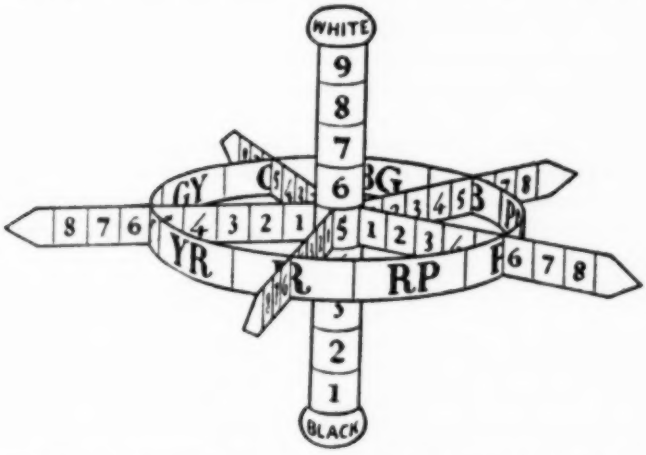

Fig. 1—Schematic diagram of the Munsell color solid, showing Hue, Value, and Chroma in their proper relation to one another.—Courtesy Munsell Color Co., Inc.

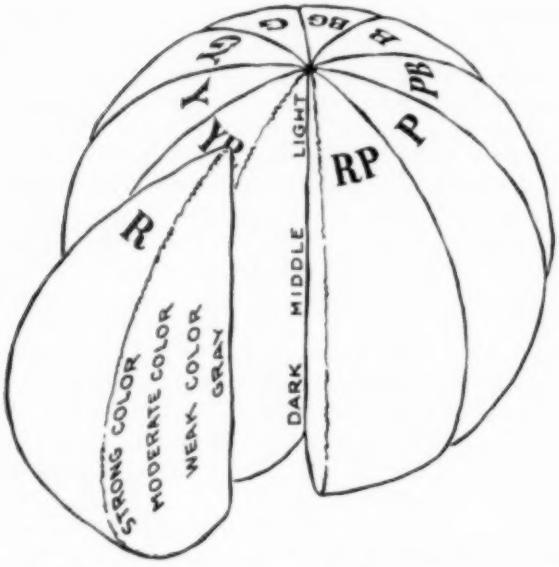

Fig. 2—The Munsell color solid represented as a ten-segment orange, each segment being one of the ten principal hues.—Courtesy Munsell Color Co., Inc.

not exist. Munsell's Atlas, published in 1915, contained colored paper chips arranged according to various sections through this solid, some passing at right angles to the value axis, others including the axis in their plane. The specification of color consisted of a numerical statement of the position of any sample on the scales established for the solid.

The Atlas of the Munsell Color System, and a revision of that work called the Munsell Book of Color,[1] published in 1929, have been used extensively in art education and in establishing color standards for foods and drugs, textiles, paints, and other industrial and commercial applications.

The Munsell notation, being based strictly upon the visual appearance of color samples, is psychophysical and subjective in nature. It involves the observation of samples by reflected, rather than by transmitted light. As such, the system is not readily adaptable to the establishment of a specification for glass filters. It will be shown subsequently, however, that the Munsell System is of value in the determination of suitable tolerances for the color requirements established for certain of these glasses.

Another color notation is that known as the ICI System.[2] This system fairly well conforms with the requirements which we have mentioned, i. e., physical measurement of color and a method of expressing the physical data in terms of what we see. It was developed by the International Commission on Illumination and introduced in 1931, and is today the most widely used numerical color notation. The system involves first of all a spectrophotometric curve, which is simply a measure, wavelength by wavelength, of the amount of radiant energy transmitted (or reflected) by the color sample being measured through

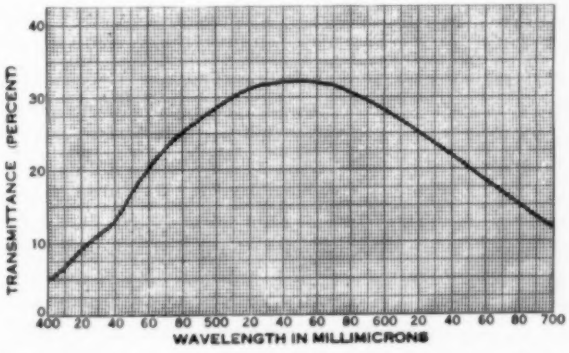

Fig. 3—Visible transmission curve of Bausch and Lomb Ray-Ban #3 shade glass at 2mm. thickness.

the visible spectrum. Figure 3 shows a typical spectrophotometric curve, in this case that of Ray-Ban glass. A curve such as this is the basic ingredient of the ICI System: it shows the relative amount of light of each component of the visible spectrum which the filter transmits. The physical difference between the various regions of the spectrum is simply one of wavelength, which varies continuously from one end of the spectrum to the other. At any given wavelength, it is an inherent physical property of a material to transmit (or, if it is an opaque material, to reflect) a certain percentage of the radiant energy incident upon it. An expression of this property for all wavelengths of the visible spectrum is a curve, such as this. It is seen that this filter transmits some of all the component parts of the spectrum, although more at the middle, or green, portion; hence the glass looks green.

A further understanding of this concept of saturation, or purity or chroma, may be obtained by a study of the spectrophotometric curve. The Ray-Ban glass is green, but it is not a highly saturated green, since it transmits, according to the curve, some of the violet, blue, yellow,

orange, and red. If the curve were to show zero transmittance through these regions and show only a sharp rise in the middle portion of the spectrum, it would then be a very highly saturated green; in the Munsell notation its chroma would be about 12 or 14, and in the ICI System its purity would approach 100%. On the other hand, if the curve were flat, showing no more transmittance in one region than in any other, it would represent a filter having no determinate hue; it would also have zero purity or chroma. Thus, the shape of the curve is a measure of the saturation of the sample.

To translate the physical data represented by the spectrophotometric curve into the desired visual, psychological data is accomplished in the ICI System by a computation involving three theoretical primaries, called tristimulus values, one of which is identical with the well-known luminosity or sensitivity curve for the average observer. The computation results in three numbers, one of which is the brightness, or per cent visible transmittance (or reflectance) of the sample, and the others are chromaticity coordinates which are plotted on a specified diagram called the chromaticity diagram. The plotted point represented by the determined chromaticity coordinates indicates what the dominant wavelength and percentage purity of the sample will be.

It is to be observed that the three components which define color in the ICI System are called brightness, dominant wavelength, and purity, as compared with value, hue and chroma in the Munsell System. The use of a recording spectrophotometer[3] developed by Dr. A. C. Hardy of the Massachusetts Institute of Technology and manufactured by General Electric in Schenectady has provided an accurate, rapid, and reproducible means of obtaining a transmittance or reflectance curve and has made the method of great importance in research and commerce.

Other method of color designation, such as the Ostwald[4] System and, more recently, that developed by Hunter,[5] are in use but will not be discussed here.

It will be readily observed that the ICI System should be quite suitable as the basis for a color specification for ophthalmic glasses. For several colored glasses, there have been established standard dominant wavelength, purity, and brightness values with suitable tolerances. As the glass is produced, a ground and polished sample of each melt is submitted for color measurement. The melt is accepted or rejected according to the conformity or non-conformity of the sample with the specification. At the same time, any noted variations in the determined color data from the specified mean are used as evidence of the need for minor changes in glass composition and/or melting procedure. The

incorporation of these changes from day to day makes possible the exercise of very strict control over the glassmaking process, resulting in the holding of color from melt to melt very close to the mean of the specified requirements.

The manner of establishing suitable tolerances to place upon the selected mean color parameters for a given glass series is an intricate and interesting problem. It necessitates a means of obtaining a close correspondence between color differences determined by physical measurement and the visual perception or appearance of these differences. A great deal of work has been done in recent years by investigators such as Judd, Nickerson, Balinkin, *et al* in the measurement and designation of small color differences, and various methods have been proposed to obtain the aforementioned correspondence. One of these is an empirical equation[6] which has been employed in our work with colored ophthalmic glasses; known as the Nickerson-Balinkin equation. It is as follows:

$$I = \left(\frac{2C}{5}\Delta H\right)^2 + (6\ \Delta V)^2 + \left(\frac{20}{\pi}\Delta C\right)^2$$

This equation, in Munsell notation, expresses perceptible difference (I) between two color samples in terms of measurable difference in hue, value, and chroma of the samples. It is particularly useful in the application in which we are interested because it allows the quantitative determination of variance in each of the three parameters which produces a certain perceptible color difference to an observer with normal color vision. By setting I equal to one, and $\triangle V$ and $\triangle C$ both equal to zero, we determine the value of $\triangle H$, the difference in hue necessary to produce the perceptible difference represented by $I = 1$. Similarly, the value of $\triangle V$ and $\triangle C$ are determined. (When $I = 1$, this does not mean that the color difference is the least perceptible difference; actually, $I = 1$ represents several minimum perceptible differences.)

With these data thus obtained, we construct a sphere, at the center of which is located the standard color of the particular glass and shade being specified, and the three ordinates of the sphere are the three parameters—hue, value, and chroma, scaled according to the determined values for $\triangle H$, $\triangle V$, and $\triangle C$ for $I = 1$. To make the spherical specification practical for routine production checking, the ordinates are translated into ICI notation of dominant wavelength, brightness, and purity, this conversion being accomplished through the use of charts[7] which show the ICI chromaticity coordinates in terms of Munsell hue and chroma. With the sphere thus established for $I = 1$, its size is reduced or enlarged according to visual examination of samples

representing certain measured color differences. A "maximum allowable difference" is decided upon, and the values representing that pair become the limit of the specification.

The significant feature of the specification is the fact that any two diametrically opposed points on the surface of the sphere represent two color samples which will exhibit the same degree of apparent color difference as any other two diametrically opposed points on the surface, regardless of whether the difference is due to variation in only one parameter or to variation in two or in all three. It follows that any two points within the sphere represent a certain color difference which will be quantitatively the same as that represented by any other two points having the same separation, regardless of their location or direction.

Such a color specification has been established and put into operation for certain of our ophthalmic glasses, and we are now extending it to others. For those glasses for which it has been adopted, it has proved to be very satisfactory. It does not follow, however, that this is the ideal color specification for all colored glasses. It will be shown that neutral glasses, for example, require a different type of specification.

Of interest are the requirements of our armed services for lenses for flying sun glasses. During the last war, the Air Force was using a glass called Rose-Smoke, a 15% transmitting glass of reddish-brown color. At the same time, the Navy was using a neutral glass known to the professions as Smoke D. The specifications for color of these glasses were quite different from each other. The specification for Rose-Smoke consisted of two visible transmission curves forming an envelope, and the requirement for conformance was that the curve of the glass at 2 mm. thickness must fall within that envelope. In a sense, a definite requirement for dominant wavelength and purity was specified, along with the more obvious requirement for brightness or total visible transmittance. The smoke glass procured by the Navy, however, carried no requirement for hue: there was specified for the glass a visible transmittance of 15%, with a suitable tolerance, and a maximum chroma (Munsell notation) of 2. Actually, a requirement for hue or dominant wavelength in this case is unnecessary, since with very low chroma or saturation, the hue is insignificant: the glass is essentially gray regardless of its dominant hue. In referring back to the Nickerson-Balinkin equation, it is seen in the $2C\triangle H/5$ expression that as C approaches zero, $\triangle H$ becomes indeterminate. In other words, with very low chroma, it makes no difference what the hue is.

A group of military medical personnel, along with experts in the fields of physiological and physical optics, formed as the Armed Services Vision Committee under the National Research Council, a few years ago recommended to the services that flying sun glass lenses for general use should be neutral in color. It was felt that perfect visual recognition of colors, especially of signals, was essential, and that the filter used as a sun glass lens should not in any way distort the visual acceptance of color values, i.e. dominant wavelength and purity. The smoke glass had been considered to be reasonably neutral, in the absence of anything better. However, we undertook to develop a really neutral glass, one having as flat a transmission curve as possible. After more than three years of development work and a great many experimental melts, we succeeded in making a 15% transmitting glass which, color-wise, was very nearly a perfect neutral: its transmission curve through most of

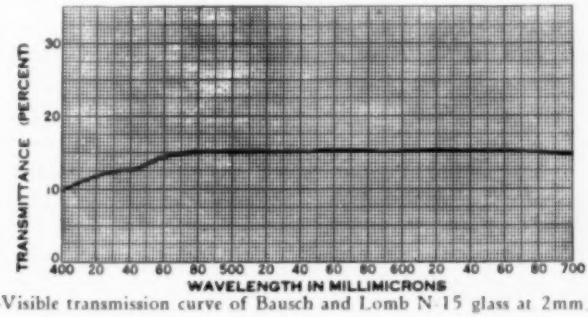

Fig. 4—Visible transmission curve of Bausch and Lomb N-15 glass at 2mm. thickness.

the visible spectrum approaches a horizontal straight line. This glass we have designated N-15. See Figure 4.

With regard to the specification of color, the neutral glasses present a unique problem. As mentioned before, the glasses are gray, and dominant hue means nothing. In addition to the specified visible transmittance for each shade, the important factor is proper specification of the "neutrality" of the filter. It can easily be shown that a requirement for maximum purity or chroma, even at a very low figure, does not necessarily insure good neutrality. Actually, the perfect neutral filter, at any given brightness level, is one with a flat visible transmission curve, and any deviation from that flat curve is a deviation from the neutrality of the filter. Dr. Deane Judd of the National Bureau of Standards, and a member of the Armed Services Vision Committee, recently developed a method of measuring this deviation from neutrality. The method consists of determining the average transmittance in each

of nine 60 mμ overlapping spectral bands across the visible spectrum, and comparing this value with the total visible transmittance of the filter; the difference in each case is multiplied by a factor, and the resulting numbers are added and the sum divided by the sum of the factors. The result is a number which is designated "percentage color deviation," and is actually a measure of the variation from flatness of the transmission curve. N-15 melts, incidentally, have a considerably lower color deviation than any other glass we have measured. They run about 3% or 4%, whereas the Smoke D runs about 18%. Judd's color deviation method has been written into the government specifications, and the N-15 glass has been adopted as the standard of procurement by the services.

This discussion, indicating superiority of the new Neutral N-15 glass, does not mean to infer that Ray-Ban glass is not perfectly suitable for sun glasses for any but the most extremely critical use. On the contrary, the green color is very pleasant before the eyes, the eyes quickly adapt themselves to the hue of the filter, and there is no significant distortion of the appearance of objects viewed in ordinary use.

Inquiries concerning various visual problems in industry present themselves occasionally. One of these had to do with excessive emission of light of the sodium D line of the spectrum, encountered in such operations as glass blowing, cyanide case hardening, electric lamp manufacture, and certain types of welding in which sodium fluxes are used. A study of the problem resulted in the development of a selectively absorbing filter which has a visible transmittance of some 37%, yet transmits less than 1% of the incident radiation at the 589 mμ Sodium D line. The filter does an excellent job of absorbing the intense yellow light, while at the same time it has sufficient total visible transmittance to allow the wearer to see clearly objects ordinarily illuminated. Since the most important requirement is sufficient absorption of the yellow light, the color specification for this glass consists simply of a required minimum total visible transmittance and a required maximum transmittance of 1% at 589 mμ.

Another special industrial filter is the Bessemer lens. It is a very dark selectively absorbing glass (transmittance 0.06% at 3 mm. thickness) transmitting principally in the green and red portions of the spectrum. It is used by steel workers in producing steel by the Bessemer process. In this process, metal containing various impurities, principally silicon, magnesium, and carbon, is loaded into the converter and a blast of hot air shot through it for 15 or 20 minutes. The load oxidizes and burns off the impurities in the order named. As the "blow" progresses,

the temperature of the material increases. The operator depends upon visual observation of the colors of the burning gases in determining the exact point at which the carbon starts to burn, at which point he must stop the "blow" and pour the metal. The color specification for this glass consists of a dominant wavelength, purity, and brightness requirement for the glass at 1 mm. thickness, since at 3 mm. thickness the glass is so dark that the spectrophotometric curve is useless.

There is no single type of color specification adequate for all filters. Whereas the specification of percentage color deviation applies to neutral glasses, this requirement is unnecessary for chromatic filters. The specification of dominant hue for chromatic filters is usually essential, while this requirement does not apply to the neutrals. The establishment of a specification for any given filter depends upon the type of filter and the visual requirements applicable to it.

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AN INFRA-RED SKIASCOPE AND OTHER INFRA-RED OPHTHALMIC RESEARCH INSTRUMENTS*

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It is the purpose of this paper to present several uses of infra-red image converter tubes in ophthalmic research instruments. Three of these instruments were assembled and given preliminary trials while the author was a graduate student at the Ohio State University. An infra-red skiascope has been constructed at the Los Angeles College of Optometry under Air Force Contract AF 33 (600) 18007 and preliminary measurements have been made.

The use of the infra-red portion of the spectrum is not new to the ophthalmic scientist, especially when measurements are to be made at low levels of luminance. The introduction of electronic image tubes[1] which convert an image produced by infra-red radiation into a visible image has alleviated some of the problems encountered when using photographic techniques.[2] In particular, these tubes, which are photomultipliers, have a much higher sensitivity than any photographic emulsions available at this time. The photosensitive surfaces are particularly sensitive to the near infra-red.

High energy in this region of the spectrum is available from ordinary incandescent tungsten light sources. Eliminating the visible energy may be accomplished by plastic filters developed by the Polaroid Corporation.[3]

An infra-red objective optometer, pupillometer, and Purkinje-Sanson image viewer will be described to demonstrate the configurations possible using the elements presently available. Extensive performance data are not available, but it has been shown that each of the arrangements is workable and it is hoped that they may find application in the future. A description of the infra-red skiascope will be presented later along with examples of preliminary measurements.

The first three arrangements are shown in Figure 1. The essential parts of each of the arrangements consisted of (1) a system for irradiating the eye with infra-red radiation, and (2) an infra-red

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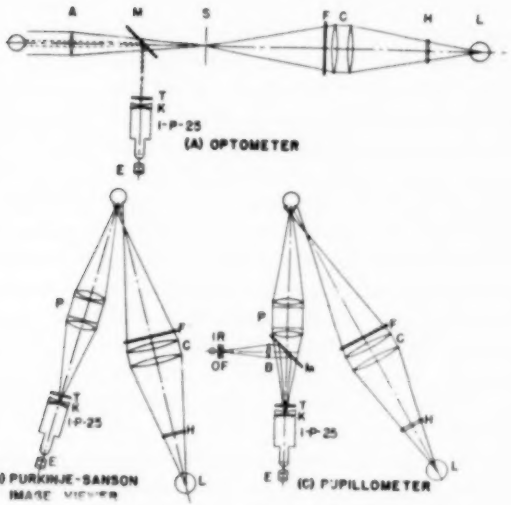

Fig. 1. Three arrangements of infra-red apparatus.

telescope arranged to view the appropriate image. These were mounted on a Bausch & Lomb Binocular Slit Lamp Base, the former on the movable arm in place of the slit lamp, and the telescope on the stationary post in place of the binocular microscope. This mounting permitted sufficient adjustment to attain any one of the three arrangements with a minimum amount of changes.

The illuminating system was identical in all three arrangements. It will therefore be described first and the viewing systems will be described below under separate headings. The light source L was a 6 volt, 18 amp ribbon filament projection bulb. The light from this source was focused by means of two condensing lenses C at the appropriate distances in front of these lenses. The light rays forming the image passed through a heat absorbing filter H and two sheets of Polaroid infra-red filter XR7X25, F. The emerging rays were thus invisible and contained only a very small amount of heat rays. The entire system was contained in a light tight housing not shown in the figures. The free aperature of the lens system was 3 inches and the system was used at approximately f:2.

Infra-Red Objective Optometer. The arrangement for this use is shown in Figure 1 (A). The illuminating system focused an image of the ribbon filament on the optometer slit S. The rays passing toward the

eye were rendered parallel by the movable lens A when it was at the zero accommodation position. These rays passing into an emmetropic relaxed eye formed an image of the slit on the retina. The reflected rays passing out of the pupil were focused on the face of the 1-P-25 image tube by lens A after reflection by the half silvered mirror M. Since the surface of the photo-cathode was curved, the image was made to conform to this curvature by placing a strong negative field correcting lens K very close to the photo-cathode. If the eye was not emmetropic or was not focused for infinity the movable lens was moved so that the image of the slit was conjugate to the retina, the amount of movement indicating the amount of ametropia or accommodation. Since the photo-cathode surface was conjugate to the slit, only the lens had to be moved.

Emission of electrons takes place from the photo-cathode in direct proportion to the intensity distribution of the infra-red energy striking this surface. A system of electronic lenses focused these electrons on the fluorescent screen at the other end of the tube. The visible image produced here was in turn viewed by the observer through an ocular consisting of the hemispherical glass end of the image tube and a 9 power Hastings triplet E.*

Because the photo-cathode was semitransparent, the subject could ordinarily see the green glow of the fluorescent screen when he looked into the movable lens. To prevent this green light from entering the subject's eye, a red filter T was placed between the photo-cathode and the half silvered mirror.

An adapting field and fixation stimulus was presented by means of a half silvered mirror placed between the movable lens and the eye.

Infra-Red Pupillometer. The arrangement for the pupillometer is shown in Figure 1 (C). The illuminating system focused an image of the ribbon filament about four inches in front of and slightly to one side of the subject's eye, thus illuminating the entire palpebral opening. The reflected light was focused on the photo-cathode of the image tube by means of a Bausch and Lomb Cinephor lens P of 3.5 inch focal length and f:2.1 aperture. The objective was used at twice the focal length giving unit magnification and a resulting relative aperture of f:4.2.

An illuminated scale was imaged on the photo-cathode by the auxiliary system shown in the diagram. The scale R consisted of transparent lines, 0.5 millimeters apart on a photographic negative. The scale was transilluminated by means of a small bulb I, a piece

*The elements for the Infra-Red converting system were loaned to the Author by the United States Navy under Contract N6 onr 225 Task Order VIII (NR 112250).

of opal glass 0, and a sheet of the Polaroid XR7X25 infra-red filter, F. The scale was imaged on the tube by the lens B after reflection at the half silvered mirror M at approximately unit magnification. A calibration was made by placing a millimeter scale in place of the subject's eye and checking it against the reflected scale. This calibration was later used to calculate the absolute pupil diameters.

The light used did not elicit a pupil reflex. This was shown by having the subject sit in total darkness for five minutes after preliminary focusing of the instrument. During this period the illuminating source was turned off. At the end of the five-minute period the source was turned on. There were no observable pupillary changes noted. This was repeated several times for several observers, each time with a negative result.

Infra-Red Purkinje-Sanson Image Viewer. The arrangement for viewing the Purkinje-Sanson Images is shown in Figure 1 (B). The illuminating system focused an image of the ribbon filament just in front of and slightly to one side of the subject's cornea. The optical axis of the system being displaced from the subject's line of sight about 15 to 20 degrees. On the opposite side of the line of sight and roughly at the same angle was placed the infra-red telescope arranged as in the pupillometer except that the mirror M and the scale projecting system were removed. It will be seen that this instrument was used only for qualitative observations.

The infra-red skiascope to be described next was developed for the purpose of determining objectively the refractive state of the eye at low levels of luminance. It is capable of measuring the refractive state of all meridians of either the right or the left eye using monocular or binocular fixation. The refractive state may be determined directly for values between one diopter of hyperopia and six diopters of myopia. This range may be extended by use of trial lenses.

A schematic subject's view of the infra-red skiascope is shown in Figure 2. The optical principles are based upon a research skiascope described by Fry.[4] A 6-8 volt, 50 candlepower source is focused on the subject's entrance pupil by means of condensing lens. The light passes through a Corning heat absorbing filter and a Polaroid infra-red XRX 30 filter. The converging light passes through a small partially silvered mirror and is reflected by a large partially silvered mirror. The final path of the bundle is normal to the plane of the diagram. The subject's entrance pupil is shown schematically in the plane of the diagram.

The subject can view the fixation point and adaptation field binocularly through the large mirror. A chin and forehead rest are

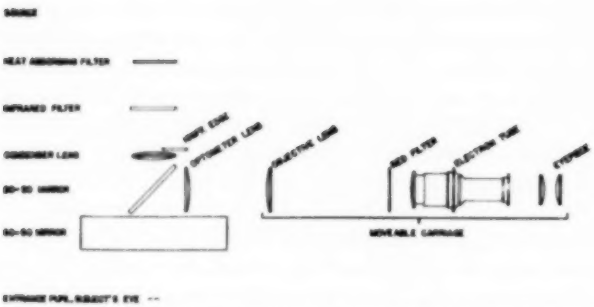

Fig. 2. Infra-Red skiascope schematic view of optical components.

provided which permit adjustment so that either eye may be measured.

A knife edge, mounted in a rotating assembly, is located directly above the condensing lens. This knife edge can be introduced into the illuminating bundle, thus producing a shadow on the subject's retina. The knife edge assembly can be rotated about the axis of the illuminating system and hence can be moved across any desired meridian of the eye.

The light reflected by the retina is reflected in turn by each of the two mirrors and thence passes through the optometer lens. The optometer lens is placed so that its primary focal point lies in the plane of the subject's entrance pupil. The light, after passing through the optometer lens, enters the measuring system. This system consists of an objective, the image converter tube and an eyepiece. A red filter is again provided to prevent visible light radiated by the tube from entering the subject's eye. The measuring system may be moved as a unit along the axis of the system. This system is moved until at neutrality the objective is placed at the conjugate point of the retina. Since the rays from the subject's entrance pupil are collimated by the optometer lens this aperture is always in focus in the measuring system.

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THE EFFECT OF TARGET VARIATION AND KINESTHESIS UPON NEAR HETEROPHORIA MEASUREMENTS*

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INTRODUCTION

In this present day and age professional men who are engaged in the scientific study of vision have recognized that ocular comfort and visual efficiency in the individuals with single binocular vision do not depend solely upon the correction of refractive errors. The importance of the analysis and interpretation of other ocular data, specifically heterophoria measurements, can not be overemphasized, when one realizes that abnormal conditions of innervation to the ocular muscles exist in so many patients seeking visual comfort. Only a small proportion of the population can be considered entirely free from some error of refraction or ametropia; similarly, one might say that for the general population a perfect state of binocular vision can be found to exist in that same limited proportion. To be more specific, "careful statistics have proved that heterophoria occurs just as frequently as ametropia, namely, in more than eighty per cent of cases."[5]

From the standpoint of attainment of binocular vision, the ideal state is visual parallelism or orthophoria. However, so-called orthophoria is often considered the exception, whereas "heterophoria is universal."[12] Generally, one regards heterophoria as a deviation of the eyes from the position of fixation when fusion is disrupted by some means of dissociation. The position the eyes assume under dissociation is considered the dissociated or fusion-free position.[12]

Now in an attempt to note the etiology of heterophoria, we must take into consideration the factors which normally affect the position of the eyes. Scobee[17] noted that these factors are divided into two types, namely anatomical and innervational. The anatomical factors are

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size, shape, and position of the eyeball within the orbit; varying action of the eye muscles by their elasticity, length, and structure; and the anatomical arrangement of the remaining fasciae and tissues of the orbit. Innervational factors are the associative movements of the ocular muscles and the other postural muscles of the neck and body; the psycho-optical reflexes including the near reflexes, fixation reflexes, accommodative reflexes, fusion reflexes, etc. The point remains that the anatomical factors are not the controlling ones in ordinary cases of heterophoria, but rather the innervational part of the neuro-muscular mechanism is of primary importance. Thus when measuring heterophoria we are measuring the position the eyes assume under the influence of many neural factors. Considering the number and variety of neural factors which influence the position of the eyes, an exact determination of this position is almost impossible.[17]

Numerous investigators in the past had undertaken the task of measuring heterophoria and establishing norms for the general population from large groups of individuals. Often the data presented by investigators were not strictly comparable because of the various methods employed, different distances of targets, and selectivity as to age, occupation, or refractive conditions.

Investigations comparing these variables have also been conducted by men in the field of visual research. For instance, Weymouth[20] compared the heterophoria measurements of a group of trained observers using three different methods. The differences found were very small, although the maddox rod test showed less exophoria than both the von Graefe prism test and the parallax test. All these results were made with the object of fixation at a seven meters distance.

Monroe J. Hirsch and Lois B. Bing[9] of Ohio State University compared the results of heterophorias taken at forty centimeters using 38 senior students. They compared the von Graefe prism diplopia test with the modified Thorington test using two different targets. The result of their efforts was that the modified Thorington method proved more reliable statistically, and it showed one prism diopter less exophoria at forty centimeters than the prism diplopia test. An unusual result of their investigation was reported when the prism diplopia test showed less exophoria using the large "E" as the target, than the lowest line of letters which the observer could read. However, these results were difficult to explain and the authors claimed this difference was due to the fact that all the observers were trained optometrists and hence used as much accommodation with the large target as they did in reading the small letters. This seemed like a poor explanation when,

due to the large letter used, there may have been proximal convergence.

In other investigations, Betts'[4] in a report on elementary school children showed that "techniques and targets used for taking phoria findings do not produce strictly comparable findings because differences in type size influence accommodation, and because of psychological and physiological differences in the situations created." Betts' found that in this specific age group the mean was 2.29 prism diopters exophoria at near. T. H. Eames[7] analysed 302 cases with regard to their age and relative heterophoria measurement, and observed a definite shift in direction toward increased exophoria with an increase in age. Monroe J. Hirsch, Mathew Alpern, and Harvey L. Schultz[10] in an analysis of 1192 cases found that at six meters, heterophoria became more esophoric, while at forty centimaters it became more exophoric with age. B. Clark[6] tested college freshmen and found that an average of 3.22 prism diopters exophoria at near existed for that age level.

Roelofs'[16] data on 238 cases under 35 years of age corroborates the common impression that myopes tend to be exophoric while hyperopes, esophoric. Whereas S. V. Abraham[1] examined 4000 subjects and found that no definite correlation existed between the error of refraction and heterophoria present. Confirming these results, Leo Manas[13] also found that on 961 cases no relationship existed between refractive error and the habitual phoria at near.

In addition to all the variables which have been mentioned previously, one must consider the daily variations in response of any single observer. E. I. Strongin and N. Bull[19] tested thirteen normal and fifteen psychiatric subjects without any attempts made to induce or measure mental, emotional, or physical disturbance. Their findings showed daily variations in degree and kind of heterophoria to compare with the temperamental changes of the subjects. "Thus, the visual apparatus begins to emerge as a dynamic system which lends itself to study in its relation to other dynamic systems of the body."[19]

In the human organism with its double nervous system we find traces of interaction within all the senses. For example, when a task requires coordination between the senses of sight and touch, the proper functioning of the visual mechanism as well as the tactile must be present. Furthermore, the relation is integrative only when the two senses agree in their report of what is taking place. The visual mechanism operates at its maximum when the task requires a precise, coordinated, synchronized evaluation from the modalities of sight, touch, and kinesthesis.

As Louis Jaques[11] so aptly stated: "Kinesthesis is probably one of

the most important subjects in optometric practice, as yet entirely ignored in optometric teaching."

STATEMENT OF PURPOSE

The visual apparatus in the course of evolution has developed to be a highly specialized and effective system. It is one of the most important means whereby the mind acquires information about the outside world. From birth onwards, the visual sense gradually associates its function with other bodily senses. Thus when an individual experiences an object as localized in space: he has labyrinthe, kinesthetic, and tactile cues in addition to the retinal image affecting his perception. In as apparently simple an act as writing with a pencil both the visual and muscular senses are involved in the performance. The image of the hand projected on the retina as it coincides with the image of the pencil is paralleled by the feeling of the hand being extended and picking up the pencil when it is used in writing. This is often referred to as hand and eye coordination. The retinal impression and muscular action are the controlling stimuli for such an act and they are interdependent.

The present report is mainly concerned with the range of modifications in the relative position of the visual axes of the two eyes, under dissociation, occurring as a result of the use of hand and eye coordination. An object seen is not an object at all but merely an image projected in space. This is shown to exist in the present investigation when each observer reaches out and touches the image in space, and in that way the effect of the tactile and kinesthetic senses upon heterophoria measurements can be noted. A secondary purpose serving to implement the main objective of this report is to demonstrate any difference in near heterophoria measurements using varying targets. In this case an effort is made to present one target to the observer which would be different by using the effect of monocular depth: and noting the change, if any, in heterophoria measurement.

In the use of varying targets for testing, an emphasis is placed upon the perceptual processes as well as on attention and interest in the stimulation of visual reactions. One can easily realize that meaning, interest, detail, and completeness are all valuable aspects of test targets. However, stimulation of the retina and attention are still not sufficient for visual perception: there has to be in addition interpretation of the retinal images by the cortex. For example, in the case of seeing in perspective and judgment of distance: it is through the innate ability of the individual and from learning the optical laws of persepctive that the visual cues are used to advantage in producing cortical impressions

of third dimension. Nevertheless men in visual research up to this date have not investigated the practical application of various psychological factors on testing targets measuring heterophoria.

OBSERVERS

Measurements were taken on fifty Chicago College of Optometry senior clinic students. The observers were selected at random from a much larger group and they all had clear, comfortable, and efficient single binocular vision. They ranged in age from twenty through fifty, were both male and female. All wore suitable glasses during the testing procedure if they previously were accustomed to do so, since it was understood that the exclusion of ametropia would not affect the results of this investigation. The visual acuity of all the observers was 20/30 or better. All had normal accommodation and convergence relationships as determined by a gradient test. No muscular imbalance at near of more than one prism diopter hyperphoria, four prism diopters esophoria, or fourteen prism diopters exophoria was observed in measurements using the rotary prisms. The observers available for study only represented a special selection from the general population.

APPARATUS

The instrument designed for this specific investigation consisted of a small rectangular box solidly fixed on a movable table adjustable for each observer. The small box was so placed as to be equidistant from either side of the table and exactly sixteen inches from the end of the table. This rectangular box had two lens openings on the front surface with a small forehead rest and a nasal depression for the placement of the observer's face. Within the small box on the left side was a mirror so placed (with a small dot) as to be at a forty-five degree angle with the observer's visual axis of his left eye when looking at the target. Thus the fixation target placed at a total distance of sixteen inches (by reflection) from the lens opening, and at right angles to the observer's left visual axis, appeared to be projected straight ahead. A dissimilar fixation target was placed an equal distance from the right lens opening, but so positioned as to be directly visible by the subject's right eye (see Figure 1). The instrument was so constructed as to allow the mirror to be fixed either before the right or left lens opening. The small dot was placed on the mirror to guarantee uniformity and to eliminate any errors caused by varying inter-pupillary measurements of observers. The instrument was free from any obstructions on both sides of the small rectangular box, thus allowing freedom of movement of either hand by the observer.

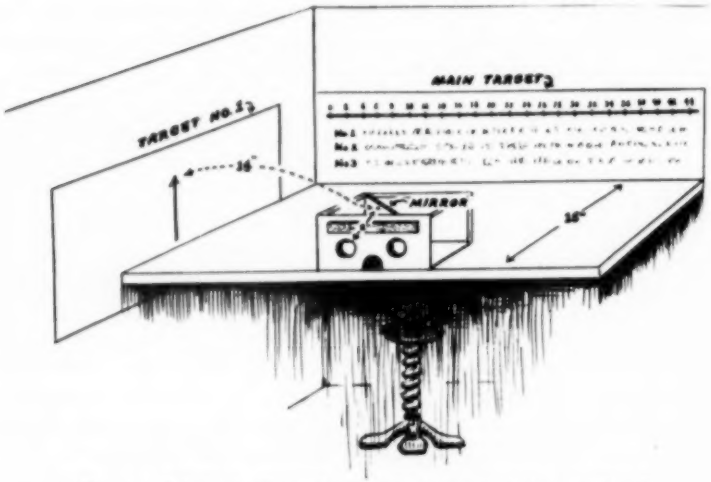

Fig. 1. Schematic illustration of the instrumentation employed.

The targets which were used in each of the tests were split stereograms of dissimilar objects. All the targets were drawn with India ink having a low gloss coefficient. The targets were made of Strathmore illustration board having a matte surface to eliminate gloss as a factor and insure a fairly uniform brightness contrast ratio for all fixation angles.

The entire background was homogeneous,white, and uniform in extent. The investigation was conducted under controlled photopic conditions with the same brightness for all observers. The main target directly obvious to the right eye in each testing procedure consisted of a row of numbers from zero through forty-four with the separation between numbers equal to one diopter. This target also provided three rows of small letters for three different testing performances to be assured that maximum accommodation was being used (see Figure 1).

In the first testing performance the target which was visible before the observer's left eye consisted of a plain arrow (see Figure 1). The second testing performance found the target consisting of two diagonal lines meeting at a common point and appearing as an arrowhead before the left eye (see Figure 2). In the third and final testing performance the target placed before the left eye was an interesting picture of railroad tracks of proportionate size with the other two targets, however the effect of monocular depth was incorporated in the target through the use of monocular cues (see Figure 3). At no time were any of the

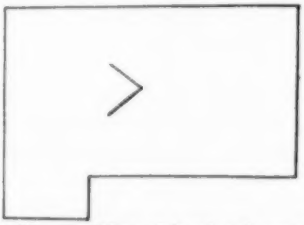

Fig. 2. Target No. 2. Effect of hand and eye coordination on heterophoria measurements.

observers informed as to the purpose of this investigation, outside of the formal reading of instructions before each testing performance.

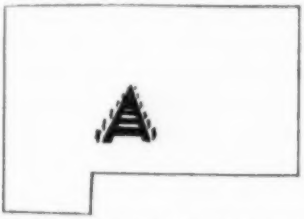

Fig. 3. Target No. 3. Effect of monocular depth on measurements of heterophoria.

PROCEDURE

Prior to collecting data for the fifty students, a careful history of pertinent factors was obtained from each. The following information was recorded: name, date, age, acuity, interpupillary distance, eye and hand dominancy, and rotary prism phorias taken at far and near through observer's ametropic correction, at near with +1.00 lens and —1.00 lens. In another room the subject was then seated in an adjustable chair and told to rest his face upon the front piece of the small rectangular box which was attached to the adjustable table. The movable chair and table were adjusted in each case so that each observer was comfortable. The brightness was kept constant throughout the testing. Three different fixation targets were used for each observer. The following instructions were given preceding each test by the experimenter:

1. I want you to get adjusted in this chair so that you are entirely comfortable.
2. Now place your forehead against this upper piece of wood and rest your nose within this depression.
3. I want you to now notice (either arrow, or arrowhead, or railroad tracks) which you see ahead of you.

4. Can you see a blurred circle? (The small dot on the mirror appears as a blurred circle when the observer looks at the target.)
5. Now I want you to move your head ever so slightly so as to place the center of this blur at the tip of the object seen.
6. Have you placed it in this position? Now read line No. (1, 2, or 3).

The randomization of target presentation was obtained by having the observer select the target number by chance from one of six small playing cards. The six playing cards had all the various possibilities in testing order of the three different targets. Each of the testing targets were placed in the instrument in rapid succession according to the order of the selected playing card. Each observer was allowed fifteen seconds to become oriented with respect to each target. Then the observer began to read the line of letters pertinent to the testing situation according to the experimenter's previous instruction. All of the lines of letters were drawn with India ink and appeared very small, subtending less than one minute of visual angle to assure use of the correct amount of accommodation. In many instances, it was almost too difficult to read, and the observers were obviously straining to interpret the script. For test No. 1 the observer was instructed to read line:

No. 1.—Now that you have placed yourself in position, tell me to which number does the tip of the arrow touch.

For test No. 2 each observer read line:

No. 2—Having placed yourself in position, complete the figure shown to be the letter "X," use pencil.

And for test No. 3 the examiner instructed the observer read line:

No. 3—You are now in position, note the depth of the tracks and which number the end touches.

At every opportunity during the testing, the observer was reminded by the experimenter to be sure that the blurred circle was placed on the tip of the object seen. All precautions were taken by the experimenter to be assured that the test results would be uniform and not subject to criticism for lack of controls in testing.

The actual measurements of the various testing procedures could all have been considered subjective responses. In test No. 1 the observer reported seeing the tip of the arrow pointing to a number on the main target. For test No. 2 the observer had drawn with the pencil the completed figure "x" on a small transparent piece of paper held by the experimenter in front of the main target. The transparent paper allowed the experimenter to notice at which point the two diagonal lines met

and thus be able to record the actual numerical reading. The primary reason for using the transparent paper was to obviate marring of the target through repeated tests. In test No. 3 the observer reported seeing the end of the railroad tracks pointing to the number on the main target. In each case the experimenter recorded the numerical reading observed on the main target.

An advantage of this apparatus was that at no time during the testing did the observer actually realize his binocular vision was dissociated, because the mirror was enclosed within the small rectangular box and not directly visible. In fact, the targets were constructed large enough to make certain that the entire background was white matte surfaced and the visual field of any observer did not extend beyond the width of the targets. Thus the field view was uniform in extent without peripheral effects and easily superimposed without any cues for differentiation. In all the testing procedures fusion was prevented by the difference in appearance of target images; however the dissimilarity of images did not hinder superimposition, thus allowing subjective responses as to the relative position of the visual axes. It should be noted that this method of measuring heterophorias is accomplished by actually moving or displacing the targets in space rather than bending the light by the insertion of prism between the eye and the targets. Generally, heterophorias are taken by dissociation of binocular vision with vertical prisms, however the experimenter believed that the projection method as described above using dissimilar images would provide additional information under more natural conditions of seeing.

Nevertheless there are three criticisms of the testing procedure using the described instrumentation. The first arises from the fact that the visual paths of the two eyes varied. Direct observation was used by the right eye and mirror reflection by the left. The observational distances to the targets were exactly the same, however there may have been a slight difference in the light transmission in the two eyes. At a distance of sixteen inches the effect was very small and not noticeable. The second criticism arises from the effect of retinal rivalry between the two dissimilar images at the point of superimposition. This effect of rivalry was disturbing at times when the observer placed the pencil on the main target in test No. 2. However, the accurary of the performance was not reduced to any appreciable amount as determined by the test-retest correlations. A final criticism which might be raised is that in measuring heterophorias with dissimilar targets very often there exists a continuous fluctuation in readings. However, when the observer was first instructed to read the small line of letters, he used the maximum amount of

accommodation for the fixation distance and the observation was made immediately thereafter. Thus the observer performed accurately and identically for all three investigations. While all of the testing situations did depend upon the observer's judgment, the simplicity of the performance and the low grade of intelligence necessary to understand the instructions render the results uniform and satisfactory for all sorts of observers.

RESULTS

The test results and other acquired data were recorded on sheets prepared especially for this investigation by the experimenter. For each individual test, three readings were taken on the first day of testing, and three more were taken on the retesting date. Thus, for each of the three tests, every one of the fifty observers had given six responses. The primary data for this investigation consisted of eighteen near point heterophoria measurements (three types of targets, three responses for each target, and retest measurements) for each of the fifty observers.

The results of the first part of the investigation, which was concerned with the determination of the reliability of the measurements taken with the instrumentation, are shown in Table 1. Score units are expressed in the raw scale units of the instrument. One may notice that for test No. 1 the average in the first test was 32.12 and the retest average was 32.24. The difference between the two means was .12 diopters at sixteen inches. A very high coefficient of correlation existed between the test and retest observations, since the "t" value for the fifty observers was 12.04.* The critical ratio was .43, far below the numeral 2.57 designating the level of significance for fifty cases. Thus the low critical ratio shows no significant difference in findings between test and retest. Similarly in tests No. 2 and No. 3, the stability of test and retest means, the consistency of test-retest standard deviations, and from test and retest reliability coefficients; one may conclude that the results in this investigation were reliable using this instrumentation.

Table II presents means and standard deviations of the three tests used in this investigation on the sample of fifty observers. The low values for the sigma of the means established the reliability of the means. The statistics were determined by combining the three test and three retest readings to make a total of 300 in all. Included in this table is a fourth test taken during this investigation measuring near point phorias with the rotary prism technique. In this manner, the author was able to establish a definite relationship between the phorias taken with the

*A "t" value of 2.69 or above is needed to show a significant correlation between the means at the 1% level.

TABLE I—TESTS FOR RELIABILITY OF DATA

	Mean	σ	r	C.R.	t
1. Test	32.12	3.5	.858	.43	12.04
Retest	32.24	3.85			
2. Test	30.346	3.68	.845	.243	19.2
Retest	30.213	3.64			
3. Test	32.31	3.6	.835	1.12	18.6
Retest	32.50	3.92			

TABLE II—MEANS AND STANDARD DEVIATIONS

Test	Mean	σ	σ^m
1.	32.26	3.74	.216
2.	30.28	3.66	.211
3.	32.40	3.80	.219
Phorias	5.14x	3.68	.52

TABLE III—INTERCORRELATIONS

Tests	Mean	σ diff	r	t	C.R.
1	32.26	.126	.827	25.55	15.7 (high)
2	30.28				
1	32.26	.10	.9045	36.4	1.4 (low)
3	32.40				
1	32.12	.456	.596	5.25	
Phorias	5.14x				

rotary prism technique and the measurements found with the instrumentation. The means of the three tests using the varying targets were expressed in the raw scale units of the instrument, whereas in all other data the conventional term of prism diopter was used.

An examination of the statistical data presented in Table III shows the intercorrelations between the various tests conducted. Thus the comparison between test No. 1 and test No. 2 in this investigation, a reliable coefficient of correlation of .827 with a "t" value of 25.55 for fifty cases demonstrated that both tests vary in the same manner. However for test No. 1, letting the observer verbally designate the number to which the arrow pointed, the mean phoria measurement was 32.26. Whereas, in test No. 2 allowing the observer use of hand and eye coordination the mean phoria measurement was 30.28. The difference between means being approximately 2 diopters, with the hand-eye coordination test showing less exophoria. The value for the critical ratio was 15.7 and therefore a significant difference between both means was apparent. One may then conclude that by use of hand and eye coordination, the measurements of heterophorias at sixteen

inches showed a definite increase in convergence over and above that measured with other tests. See Figure 4. With this procedure the

Figure 4. Graphical comparison of the three testing procedures.

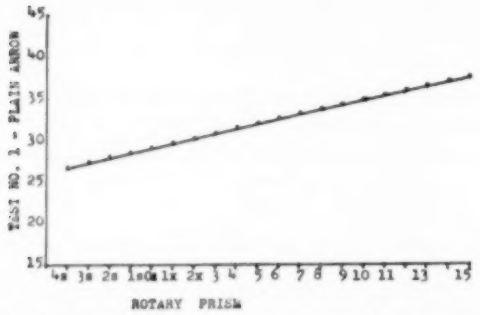

Fig. 4. Graphical comparison of the near heterophoria measurements obtained using the described instrumentation with that of the rotary prism technique.

interpretative posture of convergence was directed in space by the effective use of a pencil guided by the fingers of the hand. In this manner the recurrent association of visual pattern with the other sense patterns of the body was observed. These observations were conducted with the visual, tactile, and kinesthetic senses functioning interdependently to demonstrate resultant variations in heterophoria measurements at sixteen inches.

In his writing of psychology, Munn[14] mentioned that attention was a set or readiness to perceive. Thus attention believed to be a "preperceptive attitude" could not long be sustained unless perception took place. He maintained that perception was an awareness of meaning, and unless an image have significance it could not continue to engage the attention. During the present investigation a target was selected for test No. 3 that would have meaning, depth, and interest; so as to engage the attention and perception of all observers. Such factors as light and shade, relative size, interposition, linear perspective, and clearness of detail were used to achieve this end. The purpose was to note the effect of a target having monocular depth on the measurements of heterophoria at near.

In Table III the second comparison between test No 1 and test No. 3 showed a high coefficient of correlation of .9045 with a "t" value of 36.4 for the fifty cases. However, the critical ratio was 1.4 between these tests, and thus no significant difference between tests

existed. A critical ratio of 2.57 or better would have been needed to show that there existed a true difference greater than zero between the test targets at the 1% level. This seemed to indicate that no variation in the test target used or the type of visual perception would have any significant effect upon the heterophoria measurements taken at sixteen inches on the described instrumentation.

In the final statistical analysis in Table III the author compared test No. 1 and the near heterophorias taken with the rotary prism technique. At the 1% level a significant correlation exists for fifty cases if the coefficient of correlation is .354 or higher. As can be seen, between these two tests a significant coefficient of correlation of .596 existed, and the "t" value came out to be 5.25. The main purpose of this comparison was to arrive at a relationship between heterophorias taken with the rotary prism technique and measurements found with the present instrumentation. Such a relationship was arrived at from the regression equation:

$$\overline{X} = .566y + 29.21$$

where $\overline{X}$ = measurement on instrumentation employed
and y = measurement with rotary prism technique

The mean heterophoria measurement obtained at near with the rotary prism was 5.14 exo and with the present instrumentation it was 32.12. These statistical calculations of the means were permissible since the mean interpupillary distance at near was 61.6 m/m. and at far 64.5 m/m.

The relationships between each test were graphically shown in

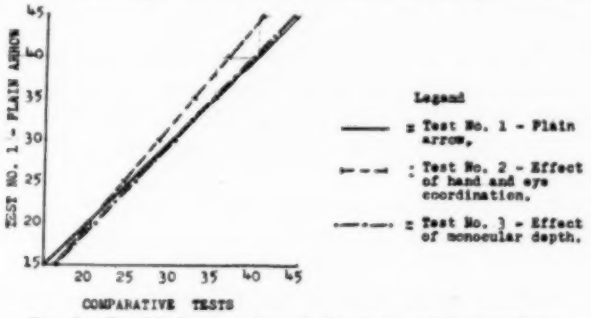

Fig. 5. Graphical comparison of the three testing procedures.

Figures 4 and 5. In the graphs the ordinate indicated test No. 1 and the abscissa the other comparative tests. The graphical representation of test No. 1 in comparison to test No. 2 showed an interesting

phenomenon. From these curves it became apparent that for test No. 2 using hand and eye coordination there was an increase in convergence in comparison to the other tests as the measurements became more exophoric. When the measurements were esophoric, test No. 2 presented a decrease in convergence. Thus the results tended to be more towards the normal or orthophoric when the tactile and kinesthetic senses acted as aids to vision. This meant that the observers during this test appeared to be able to stimulate more convergence voluntarily when the existent position of the visual axis was exophoric at near, and to relax the convergence stimulus when the visual axis assumed an existent position of esophoria at near. No significant differences could be seen from the curves comparing test No. 1 and test No. 3. In this instance the two pairs of curves show the same general pattern and any difference between them is of a questionable nature. In each of the curves, the close proximity of the lines indicates the high correlation between the tests.

A complete discussion of all the questions raised by the phenomena reported in this paper would take us too far afield from the immediate subject matter involved. However, in conclusion the experimenter would like to record his conviction that the implications of these findings should not be misinterpreted with regard to any specialized problems of perception theory. In the broadest sense, the results of this investigation show that the organism's physiological response to a given situation depends not only on that situation as it might be conceived to exist independent of the organism, but rather on the total organism-environment complex, as perceived by the participating organism.

SUMMARY

The results of this investigation may be summarized as follows:

1. Measurements of the lateral heterophorias at sixteen inches were taken on fifty senior clinic students from Chicago College of Optometry.

2. Controlled factors in testing were employed to obtain the most reliable results.

3. The purpose of this study was to note the effect of target variations and kinesthesis as an effect upon heterophoria measurements at sixteen inches.

4. Analysis of the data indicated that the instrumentation was reliable, and that differences in targets showed no significant effect upon the heterophorias at sixteen inches. However, with the use of hand and eye coordination, a significant difference was noticed between the measurements of heterophorias at near.

CONCLUSION

On the basis of this investigation, four main conclusions seem justified:

1. The high correlation between test and retest proved the reliability of the instrumentation and thus satisfactory for this investigation.

2. Under conditions of the investigation it was shown that when the tactile, kinesthetic, and visual senses were combined to record a measurement for near heterophorias, a definite fluctuation in visual behavior was noted.

3. In the present investigation, no significant variation in near heterophoria measurements was observed when different targets were used.

4. A definite relationship was established between the instrumentation used and the more common rotary prism technique for measuring heterophoria at sixteen inches.

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VISUAL TASKS IN AERIAL MAPPING WITH MULTIPLEX EQUIPMENT*

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Mapping from aerial photographs is one of the areas of human endeavor where heavy burdens are imposed on the visual ability of man. For this reason, a brief review of this field of activity may be of interest.

While nearly the same visual tasks are performed in any modern system of aerial mapping, the Multiplex system will be described here because it is highly representative, and because of its prominence in this country.

The first step in aerial mapping is obviously the taking of photographs from an airplane flying over the territory to be mapped. Since precision aerial mapping is based on stereoscopic observation and interpretation of photographic images, the flying pattern must be such that a series of overlapping pairs of photographs is obtained. Each member of a pair contains a part of the same terrain. On one member the record of this part of the terrain represents a view from a certain position of the airplane: the other member contains a view from the adjacent position.

This is a well known method of stereoscopic photography, which involves the displacement of the camera by a certain interval in the direction perpendicular to the direction of sight (or in the direction of flight in aerial photography), so that two different views of the object are recorded on the film. The interval, known as the stereoscopic base (or the air base in aerial photography) may amount, in mapping from the air, to several miles depending on the altitude of flight. While special skills are needed for the production of satisfactory aerial photographs, the visual requirements of this first step of mapping do not exceed those of usual keen observation. A pair of overlapping aerial photographs is given in Figure 1.

The processes used for transforming a series of aerial photographs into an accurate map depend on the mapping instrumentation. Until the last few years, Multiplex equipment has been used almost exclusively by

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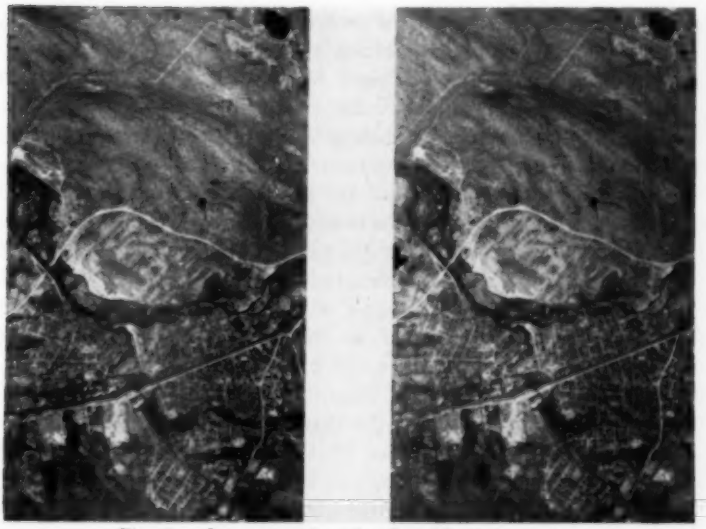

Fig. 1. A stereoscopic pair of aerial photographs.

main American mapping organizations such as the U. S. Geological Survey and the Army Map Service. The fundamental parts of this equipment are the reduction printer, a pair of projectors, and a tracing table.

The basic idea behind Multiplex equipment is the reproduction, on a smaller scale, of the spacial situation as it existed when a pair of

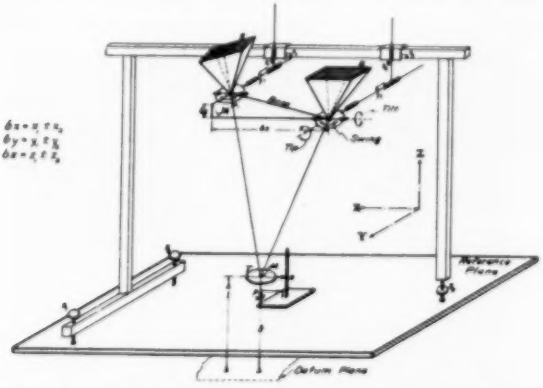

Fig. 2. A schematic representation of a camera in two successive positions in the air above a part of the terrain to be mapped. The same illustration is used to represent two Multiplex projectors above a spacial model of the terrain.

photographs was taken from the two different positions of the camera in the air. Because of this purposely produced similarity, the same illustration, Figure 2, may be used for the camera in two successive positions over a terrain, and for the two projectors suspended on the Multiplex frame above the plotting table over which the terrain is reproduced optically on a small scale.

To achieve this reproduction, the pair of aerial negatives is reduced, in the special high-precision reduction printer, from the original size of 9x9 inches to the size of about $2\frac{1}{4} \times 2\frac{1}{4}$ inches. These small positive copies of the original negatives are called diapositives. Now, each diapositive of the overlapping pair is put in the Multiplex projector. The projectors are constructed so that the ratio of their principal distance (the distance from the nodal point of the projection lens to the diapositive plane) to the focal length of the aerial camera lens is the same as the reduction ratio of the diapositives. Under this condition, the angular relationship between all the principal rays of the optical imagery will be the same for the pair of overlapping images formed by the projectors as it existed when the stereoscopic pair of photographs was recorded from the air. Then, as derived in theory and confirmed in practice, all the image rays will intersect so as to form in the space under the projectors a scale model of the original terrain. For mapping of an extended territory several adjacent pairs of projectors are used.

To make possible visual perception of this model, one image is projected on a flat surface (the "platten" of the "tracing table") in blue-green light, and the other one in complementary red light. Then spectacles with a blue-green filter for one eye, and a red filter for the other eye are used to observe the overlapping images. This is a well

Fig. 3. Multiplex equipment in use. The operator holds a tracing table with which he records details of the terrain.

known method of anaglyphic presentation of stereoscopic pairs. By means of a "floating mark" (a point of light) on a tracing table (which is essentially a specially constructed height gage) the operator can locate any detail in the spacial model of the terrain, and trace, with a pencil attached to the tracing table, the contour lines showing the ground elevations, or he may outline any features (roads, rivers, buildings, etc.) which are to be shown on the map. Thus the basic manuscript is produced which eventually is edited into a map with all the information of interest to the user. Multiplex equipment in use is illustrated in Figure 3. A map manuscript is shown in Figure 4.

Fig. 4. A map manuscript.

It is self-evident that in order to produce a manuscript of the required high accuracy, the Multiplex operator should be capable of efficiently performing the following tasks: detecting and recognizing detail in the projected image: fusing two pictures of different colors into a spacial model: bringing the floating mark into strict coincidence with the detail observed in the model: moving the tracing table while maintaining the floating mark in continuous contact with the detail which is being traced.

Hence, good visual acuity, satisfactory color discrimination, and good coordination between visual impulses and muscular movements are the primary requirements of a Multiplex operator. With all these prerequisites satisfied, the final qualification of the operator is established by his ability to measure the height of a stereoscopic image point to within 0.004". Actually, many operators can locate well defined image points with an accuracy as high as 0.002" or even better.

In his efforts to detect, identify, and measure the features contained in the stereoscopic model of a terrain, the mapping operator encounters some difficult situations.

The first difficulty lies in the fact that ideal sharpness of imagery cannot be obtained in the photographic process. Even with the best aerial lenses and the most suitable emulsions, some detail will not be reproduced with perfect clarity on the negative. The image quality deteriorates further when the negative is reduced to the diapositive, and then again when the latter is projected on the platten of the tracing table.

Thus the operator is presented with the task of observing and deciphering images which are more or less deteriorated in comparison with those he deals with in his ordinary visual routine.

Because of the unavoidable fact of imperfect imagery, thresholds of visual perception and evaluation are frequently encountered in any system of aerial mapping. Extensive research work is being conducted by many organizations here and abroad, with the aims of analyzing the specific manifestations of these thresholds in aerial photography, and of reducing the frequency of threshold situations by means of improved aerial photography. A good summary of problems, methods, and achievements of this research can be found in a series of articles recently published in "Photogrammetric Engineering."[1]

The complexity of the situation may be illustrated by the following brief outline of the problem of evaluation of photographic image quality.

The elementary method of evaluation is based on the concept of sufficient resolving power of the image-forming system, which in the Multiplex procedure consists of the following components: the aerial lens and the emulsion; the optics of the reduction printer and the diopositive emulsion, the optics of the projector, the spectacles with colored filters, and, finally, the eyes of the observer.

The idea has been that a system of higher resolution is necessarily a better system for aerial mapping, as it presents a greater amount of detail to the observer. Although the requirement of high resolution is

basically sound, it has proved to be insufficient for use as a unique measure of image quality.

Indeed, the operator observing the original aerial photographs or the stereoscopic model under Multiplex projectors (or in some other mapping instruments) uses his visual abilities not for detecting all the available detail, but only for recognizing all the features of importance in his particular assignment. The available research material shows, however, that high resolution does not necessarily secure good recognition. A factor of much importance is also the contrast rendition of detail. With exception of some special cases, it seems to be axiomatic that a picture which creates the subjective impression of high sharpness is also a picture which provides good recognition of the features contained in it. In their recent paper, G. C. Higgins and L. A. Jones[2] showed that resolution does not correlate well with sharpness judgments, and that, in some cases, resolution data are even misleading.

They found that a better measurement of sharpness is a quantity termed "acutance," which represents an evaluation of the density variation (or the "sharpness values") across knife-edge images produced by the given photographic system.

The concept of acutance seems to be very promising; but only further research can show how well the acutance value correlates with recognizability of photographic detail of interest to the photogrammetrist.

The second obstacle in aerial mapping is the optical distortion of images. In ideal imagery all the objects in a given object plane are reproduced on a uniform scale in the conjugate image plane. When the imagery is distorted, the scale is non-uniform. As a result, the image of a square may acquire the shape of "pincushion" or of "barrel" as illustrated in Figure 5. It is obvious that precision mapping is impossible when photographic images of terrain features are significantly displaced from their true positions because of distortion.

Therefore, it is really fortunate that, as a result of extensive research and development, the residual distortion in modern mapping instru-

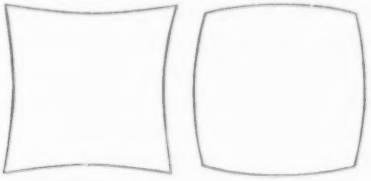

Fig. 5. Distorted images of a square. Pincushion distortion on the left; barrel distortion on the right.

ments, such as the Bausch & Lomb Multiplex, could be reduced to a negligible amount which does not exceed a few microns (one micron is equal to 0.00004") on the Multiplex diapositive. In comparison, a good telephoto lens used for reconnaisance photography may have several thousand times greater distortion without impairing the usefulness of the photographs.

As was stated previously, the stereoscopic presentation of terrain under Multiplex projectors is based on the anaglyphic principle. This involves illuminating and observing with such filters that each eye can see only the picture intended for it. Theoretically the problem may be solved with filters utilizing any pair of complementary colors. A practical solution, however, is not easy because the complementary pair must satisfy special requirements. These are: each filter should transmit as much light as possible within its transmittance band, while absorbing practically all the light transmitted by the other filter: the brightness of the colors should be nearly the same; the color characteristics of the filters should be such that their use would not create a serious problem of accommodation.

After extensive experimentation, a combination was finally selected whose characteristic transmittance curves are given in Figure 6. It should

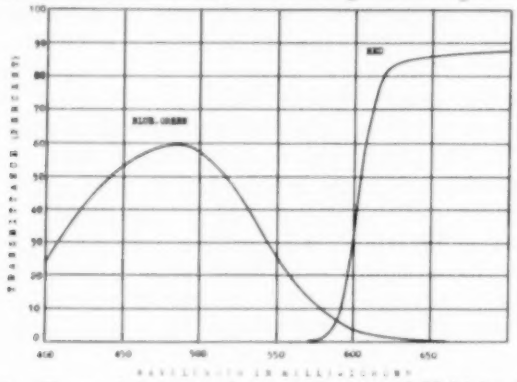

Fig. 6. Characteristic spectrophotometric curves of Multiplex filters.

be noted that although no specific complaints were received about the disparity of accommodation between the eye using the blue-green filter and the eye using the red filter, in subsequent experimentation multiplex operators tended to prefer the green filter with a correction of —0.25 diopters. This preference is natural because the eye with the green filter becomes myopic. Consequently our specifications for the green filter now call for this correction.

It should be also of interest to note that there have been no substantiated reports that would indicate that this essentially difficult method of observation has any adverse effect on the visual ability of Multiplex operators. It seems that the complaints that have been occasionally heard are of psychological nature, and are attributable to such factors as the monotony of work, the necessity of continuous concentration, and the confinement for long hours to a room, usually relatively small, which has to be darkened during the plotting operation.

As in any human activity requiring keen attention to detail, the ability to recognize and solve threshold situations, and the willingness to work under conditions which hardly can be called ideal, the profession of photointerpretation and aerial mapping is prone to encounter serious psychological situations. For this reason, the largest research organization dedicated to the study of problems of aerial photography and photointerpretation in this country, and perhaps the world, has a staff of psychologists whose efforts are concentrated on investigations of basic factors involved in this area of human endeavor. This organization is the Boston University Physical Research Laboratories under the direction of Dr. Duncan E. Macdonald. One of its members has recently summarized the basic psychological elements of the situation in a paper entitled "The Psychologist Interprets the Photo-Interpreter."[3]

A question may be asked why we go into the air in order to map the earth surface. Why not stay on the ground, and avoid all the difficulties of aerial mapping? The answer is simple. Aerial mapping, despite its own limitations, is less difficult, less expensive, and uncomparably more rapid than mapping directly on the ground.

Vast areas of the earth surface are still unmapped. According to reliable estimates, this country does not have adequate topographic maps even for 50 per cent of its territory. To cover such a large remaining territory with maps meeting modern requirements would probably be impossible even in several centuries if the conventional ground mapping methods were to be used. With extensive utilization of aerial mapping, the same work can probably be accomplished in less than one hundred years if the mapping activities of the United States agencies continue at the present accelerated rate. Aerial mapping presents many difficulties, but it is the easiest solution of the problem of rapid mapping of extended territories, particularly where many areas are inaccessible.

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AN ACCOUNT OF RECENT INVESTIGATIONS RELATING TO THE LUNEBURG THEORY OF BINOCULAR SPACE PERCEPTION*

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In the last decade the old and respectable study of visual space perception has been brought again to bloom and youthful vigor. Not the least agent in causing this ferment is the work of R. K. Luneburg, who, in three remarkable papers,[1] laid a foundation for the coherent theoretical treatment of binocularity. The appealing aspect of Luneburg's work is the straightforward use of axiomatic geometry as a direct means of characterizing binocular space perception.

The basic concept underlying Luneburg's work is that of metric or psychometric distance function, a notion which is at once simple, suggestive, and powerful in its application. This metric is a real-valued function which describes the sensory visual impression of distance between points. The existence of such a metric rests upon an almost trivial seeming property of humans, their ability to make consistently visual comparison of two lengths. From the mathematician's point of view, a metric function can be taken as the defining property of a geometry. The existence of the psychometric distance function is important, therefore, because it supplies a way of treating binocular space perceptions through the geometry of some three-dimensional continuum.

It is clear that the sensory size relation existing between two lengths need not, in fact, agree with the actual physical relation as measured by a yardstick. Ordinarily we do not make this distinction since we are so accustomed to the reliable use of our senses in getting about in our physical environment. Yet, once we are placed in a controlled laboratory situation where the familiar *environmental* clues are perverted or merely absent, this dichotomy between sensory visual size relationships and physical size relationships is immediately brought out.

It is readily apparent that the multifold environmental influences

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†Ph.D. Research mathematician to an ONR project, conducted at the Knapp Memorial Laboratory of Physiological Optics, Presbyterian Hospital, New York, New York. Presently a member of the faculty, University of Illinois.

must be rigorously controlled, restricted and delimited if we are to understand in a precise way what may be the effect of any given factor in the perception of space. Luneburg investigated the factor of binocularity alone. It was, therefore, imperative to eliminate, insofar as possible, other factors such as perspective, motion parallax, the presence of familiar objects, known surroundings, and light and shade. This condition was virtually perfectly attained in the careful experimental work of Hardy, Rand, and Rittler.[2] Their observations were made in the darkroom using as stimuli simple configurations consisting of tiny point lights dimmed to a level too low to cast any perceptible illumination on the surroundings and adjusted to appear all of the same brightness to the experimental subject. Motion was precluded by using static configurations and fixing the subject's head in a headrest. However, no restriction whatever was placed on the use of the eyes, the subject being allowed to vary his gaze at will over the points of the configuration. The value of such precautions is found in the satisfying consistency of their data in a field where consistent data are hard to obtain and experiments make large demands on the subject.

Once a situation is created in which experimental observations can be made and reproduced consistently, it becomes apparent that the determination of the character of the visual geometry through its metric is a matter only of time and perseverance. It would be possible, for example, to tabulate size matches in a way analogous to the tabulation of color mtaches in the ICI tables. Such a tabulation, properly performed, would be sufficient to specify the metric, and such an undertaking, though terribly laborious, does not appear to be altogether beyond the limits of feasibility. Luneburg proceeded more directly to the heart of the problem in a rather ingenious way.

Luneburg's method was first to utilize axiomatic geometry to arrive at a general idea as to the character of the binocular visual space. The next step was to hypothesize a correlation between the binocular stimulus and the subjective response. Finally, the theory led to experiments which would either corroborate the theoretical construction or show how to modify it to conform to reality.

It is clear that a theory constructed in this manner is in a partially fluid state, possessing rigidity up to the point where experimental confirmation ceases to exist, and after that, having a number of possible courses. In fact, Luneburg saw fit to continually modify and revise his theory in his successive papers. After his unfortunate early death, there still remained a considerable domain of uncertainty. With the help of L. H. Hardy, G. Rand, M. C. Rittler and P. Boeder, this

author was finally able to fill the gaps and complete a theory which contains all our experimental knowledge in these matters at least to the present date. It is remarkable how little has actually had to be changed in going from Luneburg's first work to the present. Indeed, hardly any of the contingencies which arose after his death had altogether escaped his inquisitive scrutiny. The reader will nonetheless be well advised to guide himself first by the latest work and to use Luneburg's first paper primarily as a source of suggestive ideas.

The two most striking results yielded by the investigations of Luneburg and his colleagues are

(1) There is a three-parameter group of transformations of the physical space, the so-called iseikonic transformations, under which binocular sensations are invariant.

(2) The space of binocular sensations is the homogeneous Riemannian space of constant negative curvature. It is a hyperbolic space satisfying the geometry of Lobachevski and Bolyai.

The first result is important because it means that we must look among the physical invariants under these transformations to determine the factors relevant to binocular space perception. In other words, those relationships among the points of a stimulus configuration which remain unchanged under a transformation of this kind are the significant ones for binocular sensation: others may be disregarded. Configurations which are related to each other by iseokonic transformation are binocularly equivalent, they have the same appearance.

The second result is in part suggested by the experiments of Blumenfeld,[3] who showed that two rows of lights set by the criterion of apparent straightness and parallelism to each other were not in agreement with rows set according to the criterion of apparent equidistance along their lengths. Such a result could obviously not occur if the binocular visual space were Euclidean. In fact, the evidence indicates that the space has negative curvature. Such a result, the reader will reflect, is not, after all, very surprising in the light of the great latitude of possibilities of binocular equivalence opened by (1). There appears to be no particular advantage in having a Euclidean visual space, and in fact, Luneburg considered a hyperbolic space to be of more potential use to the organism. Whatever the hypothetical merits of the two spaces, the experiments show that the space is, in fact, hyperbolic.

It will be recalled that the subject in the Hardy, Rand and Rittler experiments is permitted to move his eyes at will. Recently, another investigation has been initiated by G. A. Fry,[4] in which the subject is assumed to hold constant ocular fixation. Indeed, it is not unreasonable

to attempt to determine a psychometric distance function to the extent of a subject's ability to entertain visual comparisons of size under this constrained condition. Dr. Fry's efforts in this direction have led him to the conclusion that the visual space, at least under the condition of constant fixation, is Euclidean. To him this would appear to be a refutation of the Luneburg theory. Since Luneburg's theory now has considerable experimental support, it is probably not wise to reject its conclusions altogether but rather to consider the new evidence in the light of the old and see how such a state of affairs could possibly exist. In fact, without taking serious issue with Dr. Fry, it is possible to show that, as far as his results go, they do not conflict with those of Luneburg.*

Dr. Fry's assumption as to the Euclidean character of the visual space under the constant fixation condition is based upon a single experiment. It is found possible to place nine points in the horizontal plane of the eyes so that with the eyes fixed on one point, the remaining eight appear to be disposed at the vertices and the midpoints of the sides of a square, the fixation point being at the center. Fry states, "The perception of squareness is immediate and involves at one and the same moment all aspects of the concept of a square such as straight parallel opposite sides, right angle corners, and sides of equal length." Such a result compares interestingly with Blumenfeld's. However, the differences might well be attributed to the differing conditions or to another factor which is even more relevant to Dr. Fry's thesis.

It is actually true, if this experimental result has been obtained in a *variety* of different localizations and orientations of the square, and *especially with squares of large size*, that we might safely infer that visual space is Euclidean under the constant fixation condition. The importance of using large squares is underscored by the fact that *all* Riemannian spaces are *locally Euclidean*. In other words, a sufficiently small section of a curved space may, for all practical purposes, be assumed to be flat. We earth dwellers are quite used to this fact. For the purpose of surveying a farm, the laws of Euclidean geometry are sufficient; for the purpose of navigating the high seas nothing short of spherical trigonometry will do.

This locally Euclidean property of Riemannian spaces shows that Fry's experimental result would be found even in Luneburg's case, with no restriction on ocular motion, provided the configuration is restricted

*The reader has undoubtedly reflected that it would be possible to dismiss the apparent conflict on the basis of differing experimental conditions. However, there is an even more satisfactory way of resolving the situation.

to a sufficiently small region of the binocular visual field. It is actually very likely that Fry did not use large squares, since for configurations of sufficient size most of the points would be seen double and the experimental difficulties would be almost insuperable. Fry gives no data.

It is quite probable that Dr. Fry has not succeeded in establishing the Euclidean character of visual space under the condition of constant fixation, but merely found it to be locally Euclidean. From this result it can only be inferred that the space is one of an uncomfortably infinite family, the Riemannian spaces.

A good part of Dr. Fry's paper is devoted to an attempt by heuristic analysis to describe perceived distance in the frontal direction as a function of physical distance or of convergence angle. In effect, Dr. Fry assumes that perceived distance must be in close agreement with physical distance in a person's immediate neighborhood, for otherwise the individual could not function effectively. Similar arguments were advanced by Helmholtz and von Kries[5] who arrived at similar conclusions. It is quite evident from context that the situation in which such agreement is expected to hold is one where any number of factors over and beyond binocularity may be present. It follows that these conclusions shed no light whatever on binocular function. Fry gives no experimental data in this connection.

Dr. Fry's basic contribution has been to open up the possibility of investigating binocular visual space under the condition of constant ocular fixation. To date it can hardly be said that there is much progress along these lines. A solid theoretical foundation like that of Luneburg's is lacking. There is also no connected program of experiment like that of Hardy, Rand, and Rittler. The idea remains a seedling and it would be very gratifying if future investigators would take this suggestion of Dr. Fry's and make it bear fruit.

In connection with Fry's paper it may be well to mention the work of A. S. Gilinsky.[6] Miss Gilinsky has conducted an experimental program to determine the connection between perceived size and perceived distance. These experiments were not conducted in the kind of carefully controlled environment required for the Luneburg work. Miss Gilinsky errs, therefore, in believing that her work can be connected to the Luneburg theory. There is value, however, in her experimental results which show what kind of performance may be expected when the usual environmental factors are admitted. In fact, her results are not unlike those of Dr. Fry's heuristics.

A second paper by Fry,[7] pointing out differences between Luneburg's work and his own, is rendered obsolete in great measure since it

only takes account of Luneburg's first paper and was written before the appearance of the joint work of Hardy, Rand, and Rittler with this author which supersedes all the earlier papers.

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ANNOUNCEMENTS

NATIONAL SCIENCE FOUNDATION GRADUATE FELLOWSHIPS

According to an announcement made by the National Science Foundation in April a total of 556 fellows were selected from 3298 applicants to receive graduate fellowships under this program. The list of fellowship winners includes 515 predoctoral and 41 postdoctoral candidates. The scientific fields served by these awards and the number of grants to each were, chemistry, 129; physics, 115; engineering, 63; mathematics, 56; zoology, 38; biochemistry, 35; geosciences, 26; botany, 19; microbiology, 18; biophysics, 14; medical sciences, 13; genetics, 11; psychology and anthropology, 10; and agriculture, 9. Nearly three million dollars in grants have been awarded by the Foundation to institutions throughout the nation for support of basic scientific research and related matter since the start of the program in 1950.

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SHEARD COMMEMORATIVE VOLUME—OPPORTUNITY TO HONOR A GREAT MAN OF SCIENCE

The American Academy of Optometry has, this year, decided to honor Dr. Charles Sheard. We have decided that the best way to do this would be to publish, in one volume, his most significant writings relative to optometry—a "Sheard Commemorative Volume."

This will make the writings and wisdom of Dr. Sheard more readily available to all men now in the field of visual care, and to those who will follow in the years to come. Advancement in knowledge, service and understanding will always rest upon the work of the pioneers. Dr. Sheard has always had the viewpoint of the pioneer—

as well as the viewpoint of the scientist—looking forever forward.

This year Dr. Sheard has just passed his 70th birthday. During this year, he will also celebrate his 50th year in the field of optics and optometry—a truly fine span of years in which he has made many notable contributions to optometric science and to the field of professional relationships.

The Commemorative Volume we plan to publish in honor of Dr. Charles Sheard will be a 300-400 page book, cloth bound and duly inscribed in his honor. It will be entitled "Essays on Ocular Convergence and Accommodation with inclusion of monographs on Dynamic Ocular Tests, Dynamic Skiametry, Ophthalmic Optics and other contributions concerning the problems of Binocular Vision."

In order to carry this project to completion this Fall so that the Academy might further honor Dr. Sheard at its annual meeting in December, we will need the support of many optometrists. The Academy must raise a fund of about $8,000 for several thousand copies of this book. To do this, we need the financial and moral support of all those interested in optometry and the science of vision, as well as all the members of the Academy.

Each person making a contribution will (1) receive a copy of the book, mailed prepaid to him as soon as it is published, and (2) will have his name placed in a special section of the book as a friend of Sheard who helped to make this volume possible.

We are asking all those who can, to contribute $25.00. If you wish to help and feel that you cannot send us the $25.00—select any amount between $10.00 and $25.00 and send it to the Secretary-Treasurer of the American Academy of Optometry, Dr. Carel C. Koch, 1502 Foshay Tower, Minneapolis 2, Minnesota, at once, so we can enroll you as a participant in the project and to enable us to make the necessary arrangements with the publisher as soon as possible.

We are certain that most of the readers of these words will wish to contribute to this worthwhile project. It will not only serve to bring honor to a man who has given most of his life to help others, and himself to understand the processes of vision better—it will also serve to honor optometry and what it stands for. It will aid the future student of optometry. And, in the last analysis, it will aid you by bringing you a richer and fuller understanding of vision.

MEREDITH W. MORGAN, JR.

SPECIAL REPORT

CYCLOPLEGICS AND MYDRIATICS — WHAT POSITION SHOULD OPTOMETRY TAKE, IF ASKED TO USE THEM?

Carel C. Koch†
Minneapolis, Minnesota

There are definite indications that, sooner or later, optometrists are going to be face to face with the proposal that, with certain cases, and in certain specific situations, they use a cycloplegic as do British optometrists in doing a portion of their refractions, or that they use a mydriatic in doing some of their ophthalmoscopic examinations, or that they use surface anesthetics for the sole purpose of using a tonometer. It will not be proposed that these refraction and examination tools be used all of the time by optometrists, but it will be suggested that optometrists use them occasionally where indicated in the public's best interest.

Where will this proposal originate? The writer predicts that it will come to optometry from either sociologists, psychologists or educators or from welfare administrative people with the support and backing of certain ophthalmological leaders.

This suggestion is sure to arouse all sorts of mixed emotions among optometrists. The writer is not recommending the adoption or approval of the proposal—or its rejection. The purpose of this report is to place the matter before the profession to enable optometrists to think and talk about the idea and to, in time, formulate some proper collective course of action for future use, if and when the proposal is made.

Initially, the writer believes that most optometrists will be opposed to the proposal, some because they sincerely believe that the use of cycloplegics in refractive work is unnecessary. Others because they are opposed to change of any sort. Others may fear that medicine may use this as a means of dominating optometry, and still others may oppose it because of the time, effort and work involved in getting many State optometric laws amended to permit the practice.

During the entire lifetime of the profession in America, optometrists have asserted that in all, or at least the very great majority of cases,

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a satisfactory and proper eye examination and refraction may be made by those skilled in the proper techniques without using a mydriatic or a cycloplegic. The success already achieved by optometrists over the years certainly substantiates this contention. Optometrists have pointed out that refracting, as we now recognize it, started about 1840, and the use of atropine or homatropine as a cycloplegic was not introduced, or even suggested, until the late 1880s, and did not achieve anything like popularity, even among some of the oculists of that day, until the turn of the century. Even then many medical refractionists used the drugs but sparingly, if at all.

During the past 60 years, optometrists in the United States and Canada have been trained to do skillful refractions without using cycloplegics. On the other hand, most centers in which present day ophthalmologists are trained instruct these men in the use of these drugs. This is not entirely true as the ophthalmologists trained by Lancaster are "dry" refractionists. The public is, therefore, confronted with two groups of practitioners—the optometrist trained to do the work without an artificial paralysis of the ciliary muscle, and the ophthalmologist trained to refract with accommodation suspended. The question of the use or non-use is not necessarily associated with which group, optometrists or ophthalmologists, is doing the best refracting at the moment. This issue could never be settled since neither group would or could ever afford to say that the other group does a better job. The question is, could optometry do a better job of optometry if it could use either or both a cycloplegic or a mydriatic. There is probably less question about mydriatics.

There is just enough variation in techniques, in doing the work either with or without "drops," to make the job seem harder to one entirely conditioned in one technique when he is suddenly called upon to employ the other. This is one of the reasons why optometrists have contended that the use of a cycloplegic confuses the findings in collecting useful refractive data, whereas those ophthalmologists, who regularly use cycloplegics in refracting, do not find this to be true. It is evident, too, that many of the near-point tests regularly employed in optometric refractions could not be made with the ciliary muscle inactive.

In considering this question we have the optometric group who claim that the use of cycloplegics in refractive work is unnecessary and who, to a great extent, are happily licensed under laws which prohibit its use, and ophthalmologists, on the other hand, who use cycloplegics and mydriatics and find these to be of value in certain cases.

Optometrists are today doing a substantial part of the U. S.

Military eye examining and refracting. There are evidences that they will do more and more eye work in the industrial field of occupational vision. Educational authorities, too, are beginning to turn to optometrists to carry on the visual care programs given the students in our elementary schools. Many city, county and state health programs utilize the services of optometrists for indigent patients and other individuals receiving health care under various programs. All of this activity is bringing the work of optometrists under the direct and careful scrutiny of administrative people who are charged with making these programs work at a high level of efficiency.

In general, those working with optometrists are pleased with the present results. Military people have rather universally agreed that optometrists do a good job of examining and refracting. In industry, too, where the work of the optometrist has been on a fee basis, the results have been excellent. The same holds true of those health programs operated by units of government in which optometrists have participated.

In all of these fields the doors to optometric participation have been opened, and more and more optometrists will contribute their services to them in the public's interest in the future.

As they do, however, the question of the advantages and disadvantages of using cycloplegics, or in some cases mydriatics, will come up many times in the future, as it has in the past. In the military services, under some commands, optometrists have refracted with cycloplegics. Under other commands, the use of the cycloplegic has been optional, and most of the refractions were made without the drug.

In other situations, the administrative people in insurance programs, education and health programs are at times conditioned by their own private experiences and what they have heard on the subject. Some of these administrative people who have worked closely with certain ophthalmologists in the past are prone to look with favor on the use of cycloplegics in refraction, at least in certain cases.

In some of these situations physicians serve as top administrators in health matters, and these men are influenced—and naturally so—by ophthalmological associates, to be partial to refractions made under a cycloplegic.

Social workers and nurses, too, frequently have been conditioned to the use of the drug in refractive work. Many are prone to question the accuracy of refractions—particularly those made on young children —when no cycloplegic has been used.

Certain ophthalmologists also believe that our work as optome-

trists could be done more effectively if we used cycloplegics in occasional cases. They feel that in squint cases and high hyperopias in children, we, too, would find the drug of value once we became accustomed to using it in these cases. They also believe that in picking up suspected cases of ocular pathology, we would be in a position to do an even better job than is now being done by optometrists, if a mydriatic were employed in these cases, or if we used surface anesthetics to enable us to use tonometers as an aid in detecting glaucoma.

There are certain more or less intangible signs that these proposals are crystallizing into something akin to a clear and concrete proposal that optometry include among its examining and refracting techniques, the use of certain cycloplegics and mydriatics. If this comes to pass, some time in the future, optometry must have all the facts relating to this question at hand to be in a position to discuss the proposal in a factual and not an emotional manner.

The writer, as has already been said, is not supporting this matter. He has not attempted to gather together the data which might be compiled to support such a suggestion; nor has he compiled the data which might be used to offset or refute such a proposal.

In certain points of contact with professional leaders, the writer has a growing conviction that, before too long, a serious suggestion will be presented to organized optometry to the effect that optometrists use cycloplegics and mydriatics in certain cases to further improve their work in the public's interest. This proposal will probably not come to optometry in a critical manner; nor will it come from a source which can be ignored.

If, and when, this happens, the writer believes the matter should be approached in a slow and serious manner—also in an objective way. The suggestion or proposal, when it comes, will probably come from friends of optometry, or at least individuals who have come to recognize that optometrists are already making a real contribution in the field of health work, and who believe that this can be further improved.

The writer hopes the proposal will be considered from that aspect by those chosen in optometry to study the matter and to consider it from all angles. To this group will go the task of preparing a formal report to guide the profession in making its decision and, later, its reply to the proposal. In the meantime, optometrists everywhere may reflect on the matter and discuss its possibilities.

CURRENT COMMENTS

Terry Judith Parkins
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

WHY USE ORTHOPTIC TECHNICIANS?

The recent announcement[1] of a basic course in orthoptics, sponsored by the American Orthoptic Council makes us wonder just what is expected of these girls by the ophthalmologists who adminster this activity. The course mentioned, calls for a two-month residence training period in the Department of Ophthalmology of one of our Universities, followed by seven months of practical clinical training under the supervision of a certified orthoptic technician. At the end of this training period, the candidates are then eligible to take the examination given by the American Orthoptic Council and, if successful, be certified as orthoptic technicians.

To be sure these girls are supposed to work under the personal and direct supervision of ophthalmologists and, consequently, it may be presumed that it is not essential that they have much basic training in the visual sciences. Yet, nevertheless, it is evident that in this short period of training they can learn very little of fundamental value about the work they do.

It occurs to the writer that it would be far better to urge these girls to become practical nurses and thus enable them to serve the entire public in a field where there is a real shortage of workers.

In general, I am told, it has been the experience of many optometrists that orthoptic training is indifferently carried out in many clinics, if attempted at all. This, of course, may be due to lack of interest in the subject or to inadequate evaluation of the fundamental aspects of vision on the part of the examiner. In any event, it seems obvious that improperly trained technicians cannot improve the situation nor possibly interpretate refractive or clinical orthoptic data to enable a good training job to be done.

Why should ophthalmologists who need help in their offices or clinics hesitate in appointing staff optometrists to serve in their full professional capacity in doing refractions and orthoptic work? This would relieve the medically trained personnel for therapeutic and

[1]News Notes and Comments. Eye, Ear, Nose and Throat Monthly. 32. June. page 338. 1953.

surgical eye work. This has already been done with considerable success in a number of offices and clinics. Where the need exists it solves all problems without introducing inadequately trained technicians who require supervision and detailed instruction in every step of case procedure. To be successful, of course, the optometrist must be accorded his full professional rank in the clinic. He must serve as an optometrist and be given professional responsibility for all work assigned to him.

Ophthalmologists will find that he will handle this responsiblity well. Besides being excellent examiners and refractionists optometrists are also well trained in the basic concepts underlying orthoptic work and in the various techniques employed. The present five-year undergraduate optometric professional courses cover these subjects very thoroughly and such a licensed practitioner would certainly be of far more help in an eye clinic than an orthoptic technician. It is quite possible that an additional number of young optometrists might consider such appointments.

Or, if this is out of the question—as there is a shortage of optometrists in many areas—why still attempt to utilize orthoptic technicians? It seems to this writer that ophthalmologists should reciprocate with optometrists in their local communities by sending them their cases requiring orthoptic training. In doing so it would make the consultation area between optometry and ophthalmology a two-way street and would usually result in far better service to the patient. In addition, it would enable ophthalmologists to show their appreciation for the referred cases of pathology they receive from optometrists in private practice.

WAHL RE-ELECTED A.O.A. CHIEF

Dr. James Wahl, Anna, Illinois, was re-elected President of the American Optometric Association at its 56th Annual Congress, Rochester, New York, June 21-24. Other officers re-elected are Dr. S. L. Brown, Fostoria, Ohio, First Vice-President; Dr. N. B. Hays, Niagara Falls, Second Vice-President; Dr. J. M. Babcock, Portsmouth, Ohio, Third Vice-President; Dr. R. E. Flower, Visalia, California, Fourth Vice-President; Dr. E. H. Kiekenapp, Minneapolis, Minnesota, Secretary, and Dr. L. G. Miller, Lincoln, Nebraska, Treasurer. Dr. L. Sugarman, Meridian, Connecticut, was elected trustee to take the place of Dr. J. Ottis White, Baton Rouge, Louisiana.

The 57th Annual Congress of the A.O.A. will be held at Seattle, Washington in June, 1953.

STRAWN JOINS C.C.O. BOARD

Dr. Eugene Strawn, Freeport, Illinois, was elected a trustee of

Chicago College of Optometry at its annual meeting, June 16 in Chicago. Dr. Strawn replaces Dr. Louis Falk, who was unable to continue as a trustee. Dr. Sidney Levinson, Director of the Michael Reese Research Center of Chicago, was re-elected as a trustee. The other trustees are Dr. Samuel Hauser, Chicago; Dr. Oscar W. Weinstein, Rockford, Illinois; Dr. Henry Wolff of Marshalltown, Iowa; Mr. William Weinress, Chicago, Illinois; Dr. Carel C. Koch, Minneapolis, Minnesota. Dr. Hauser serves as President of the Board of Trustees, Dr. Levinson as Chairman of the Executive Committee. The officers of administration of the college are Dr. Morton Abram, President, and Dr. Eugene Freeman, Dean.

OMEGA BETA SIGMA

A meeting of Omega Beta Sigma, optometric honor society, was held at the Los Angeles College of Optometry, June 3, at which time the successful candidates of the graduating class of Los Angeles College of Optometry 1953 were inducted into membership. These were John Aitken, Theodore P. Chlepas, Earl D. McKenna, R. James Beaumont, Misao Matoba, Jack Parry, and Raymond Sommer. Richard Garabedian, Norman R. Miller and Melvin Nadell of the class of 1953 were admitted to membership as senior students.

Dr. Robert S. Eakin of the class of 1945 was also admitted to membership at this meeting.

Elected to office for the next fiscal year were Dr. Harold Firestone, President; Dr. Robert Graham, Vice-President and Dr. Wm. N. Brisbane, Secretary-Treasurer. Inquiries regarding Omega Beta Sigma should be directed to Dr. Wm. N. Brisbane at the Los Angeles College of Optometry, 950 West Jefferson Blvd., Los Angeles 7, California.

NEWS BRIEFS

The Optometric Society of Greater Kansas City has arranged a program to supply emergency refractive care and glasses to disaster victims in the event of an air raid in the area. Instruments and materials would come from a special stockpile. Medical and pharmaceutical societies have comparable programs in their fields. The activity is part of the local Civil Defense program. . . . Dr. Ralph Smith Minor, retired dean of the School of Optometry at the University of California, was given the honorary degree of doctor of science at the 143rd commencement on June 14 at Hamilton College, Clinton, New York. Dr. Minor, who retired in 1946 held the deanship of the School of Optometry for 23 years. . . . The degree of Doctor of Optometry, was awarded to 60 students of the College of Optometry, Pacific

University, on May 24. These students had completed their fifth year of professional studies. . . . The Winnetka Readability Chart which has been out of print for some time is now available for distribution by the Division of Publications, The Reading Clinic, Department of Psychology, Temple University, Philadelphia. . . . Beta Sigma Kappa held its 29th annual convention in Rochester, New York, June 23. Chancellor, Dr. Harry E. Pine, Chicago, Past President of the A.O.A. presided at the meeting. . . . More than 1,600 new members have been signed up by the Better Vision Institute during the membership drive this Spring. Most of these are individual optometrists in private practice. The total membership is now over 4,000 and many additional members are expected to join during the summer months. . . . The new building which will house the College of Optometry, University of Houston, was dedicated on June 8. At that time the Texas Optometric Association presented the University of Houston with its second year check for $20,000 as part of the total pledge of $100,000 to be paid over a five-year period. . . . Dr. Arthur Shlaifer was elected president of the Pennsylvania State College of Optometry Alumni Association at its annual meeting June 6-7, at the College, Philadelphia. . . . The National Technical Conference on Lighting conducted by the Illuminating Engineering Society will be held in New York City, September 14-17, Hotel Commodore. Several papers of interest to optometrists will be presented and members of the profession are invited to register. . . . Dr. Henry W. Hofstetter, director, the Division of Optometry, Indiana University, Bloomington, announces the appointments to the faculty of Merrill J. Allen, Ph.D., as associate professor, and Joseph S. Rafalko, Ph.D., as associate professor. Dr. Allen was a faculty member at the School of Optometry, the Ohio State University, and Dr. Rafalko was a faculty member at the Southern College of Optometry.

BOOK NOTICES

GIFFORD'S TEXTBOOK OF OPHTHALMOLOGY. Fifth Edition. Francis H. Adler, M.D. Professor of Ophthalmology, University of Pennsylvania Medical School. Published by W. B. Saunders Company, Philadelphia. 488 pages. 26 color plates. 281 illustrations. Cloth. $7.50. 1953.

The problem of the optometrist and general physician regarding diseases of the eye are essentially the same. Both have the responsibility of recognition; however, they usually cannot and need not make a

differential diagnosis. For this reason Gifford's textbook of Ophthalmology, which was written principally for the general physician, undoubtedly will be found very useful by optometrists.

In order to recognize diseases of the eye it is necessary for the optometrist to be thoroughly familiar with the normal eye. In addition, he must have a basic knowledge of the commonly encountered diseases of the eye.

The poorest textbook for an optometrist on ocular diseases is one that abstracts the whole of ophthalmology. The best textbook is one that specifically meets his needs in practice. On this basis, this latest edition of Gifford's text is excellent.

The book contains clear and adequate explanations of diseases of all the structures of the eye and its appendages. Also, chapters are included on ocular disorders due to diseases of the central nervous system, ocular manifestations of general diseases, and therapeutic agents used in ophthalmology. Of particular and special interest to optometrists is the chapter on general indications for operative procedures.

In this edition, Adler considerably enlarged the sections on the hypertensive diseases, especially hypertensive retinopathy, and diabetes. Also, much new material has been added, particularly in the field of therapeutics, to keep pace with the recent developments in antibiotics, the use of ACTH and cortisone. It appears that every effort has been expended to make this edition a practical manual and one that would be found very instructive and useful to optometrists.

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TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

ACADEMY LUNCHEON

Seventy-one Academy members and guests joined in an informal luncheon during the American Optometric Association Annual Congress, Seneca Hotel, Rochester, New York, June 23. Dr. Morton Abram, luncheon chairman, presided. Dr. Meredith W. Morgan, Jr., Academy President, spoke on the areas in which Academy leadership could improve the part optometry was to play in the health programs of this country, and the need for active and close cooperation between the Academy and the A.O.A.

CHAPTER ACTIVITIES

SOUTHERN CALIFORNIA CHAPTER

Dr. Leo Tankan, ophthalmologist, spoke at the June 12 meeting of the Southern California Chapter. His subject was "Diabetic Retinopathics: Hypertensive Retinopathies and Esotropia." Dr. Hugo E. Apel presided at the meeting.

FLORIDA CHAPTER

The annual meeting of the Florida Chapter of the American Academy of Optometry was held in connection with the Florida Optometric Association convention in Jacksonville on June 14, 1953. The speaker was Dr. Irving Filderman, President, Tennessee Chapter of the American Academy of Optometry. His subject was Sub-Normal Vision and Its Correction.

The next meeting will be held in Orlando in January, 1954, following the American Academy of Optometry annual meeting. The speakers will be Dr. S. B. Schumacher, Jacksonville, and Dr. Ester Ingram McCrory, Winter Haven.

Officers elected were: Dr. James F. Loomis, re-elected President; Dr. Karl Eychaner, re-elected Vice-President; Dr. Jack Bumpous, re-elected Secretary-Treasurer.

NORTH CAROLINA CHAPTER

The Spring meeting of the North Carolina Chapter was held on June 14 at the Hotel Robert E. Lee, Winston-Salem, North Carolina.

Following the presentation of several papers the following officers were elected for the coming year: Dr. Mordecai Katzin, Jacksonville, President; Dr. R. J. Pearce, Greensboro, Vice-President, and Dr. John D. Perry, Jr., Winston-Salem, Secretary-Treasurer. The officers and the following members constitute the Executive Council: Dr. J. Smith Nifong, Winston-Salem; Dr. Herbert L. Toms, Concord, and Dr. Henry B. Day, Sr., Raleigh.

NEW MEMBERS OF THE ACADEMY

The following optometrists and educators were elected to Fellowship in the American Academy of Optometry during the quarter ending June 30, 1953. The Academy welcomes these new members:

Dr. Charles A. Abel, Los Angeles College of Optometry, 950 West Jefferson Blvd., Los Angeles, California.

Dr. Morton Clyde Flom, School of Optometry, University of California, Berkeley, California.

Dr. Douglas B. Freeman, R.O., 203 Brant St., Burlington, Ontario, Canada.

Dr. James Gregg, Los Angeles College of Optometry, 950 West Jefferson Blvd., Los Angeles, California.
Dr. Robert K. Morrison, 12½ West Winter St., Delaware, Ohio.
Dr. Charles W. Ott, Northern Ilinois College of Optometry, 4170 Drexel Blvd., Chicago, Illinois.
Dr. Edward C. Scanlan, Northern Illinois College of Optometry, 4170 Drexel Blvd., Chicago, Illinois.
Dr. Robert Spreat, Pennsylvania State College of Optometry, 12th and Spencer, Philadelphia, Pennsylvania.
Dr. Arthur H. Tweedle, R.O., 305 King St., Midland, Ontario, Canada.
Dr. Frank W. Weymouth, Los Angeles College of Optometry, 950 West Jefferson Blvd., Los Angeles, California.
Dr. Vincent Zunica, 9342 Central Park Ave., Evergreen Park, Illinois.

NOTE ON COMING ACADEMY MEETING.

Dr. Helen M. Robinson, director of the Reading Clinic, The University of Chicago, has invited interested Academy members to visit the Reading Clinic during the coming meeting of the Academy in Chicago, December 5-8, 1953. This invitation has now been accepted and the Papers and Program Committee is arranging time for this open house at the University during the four-day Academy paper-packed sessions.

CORRESPONDENCE

FIELDS OF FIXATION

To the Editor:

The statement, ". . . average values for the fields of fixation are 60 degrees up, 75 degrees down, 60 degrees in and 100 degrees out," made by Zinnecker and Ellerbrock in the Am. Jl. Optometry 30:202, April, 1953, has not been noted in subsequent issues, as an error. Although it is obvious an eye cannot turn 100° outward, such a statement might be quoted again by the unwary.

PAUL W. MILES, M.D.
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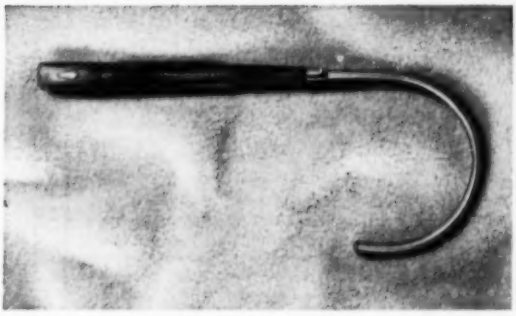

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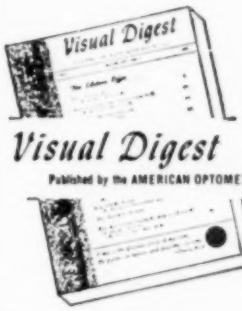

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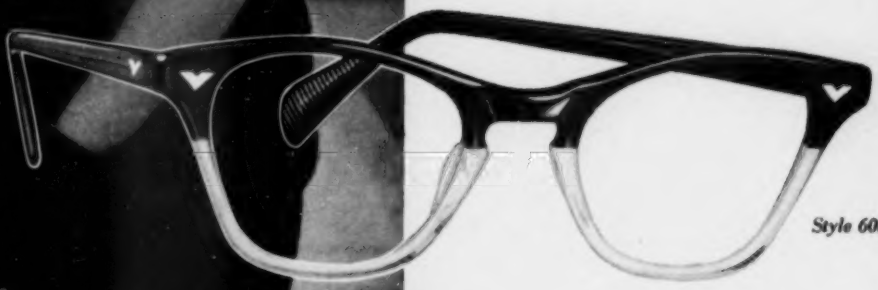

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